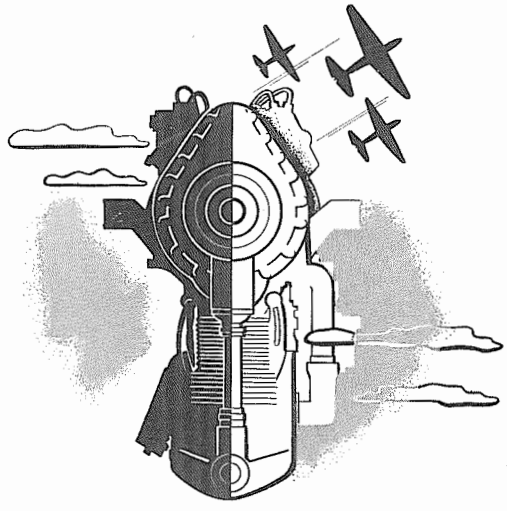
Ranger

OVERHAUL MANUAL



6-440C

RANGER AIRCRAFT ENGINES

Division of Fairchild Engine and Airplane Corporation

Farmingdale, Long Island, New York

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Farmingdale, N. Y., U. S. A.

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The above constitutes the sole warranty of Ranger Aircraft Engines.

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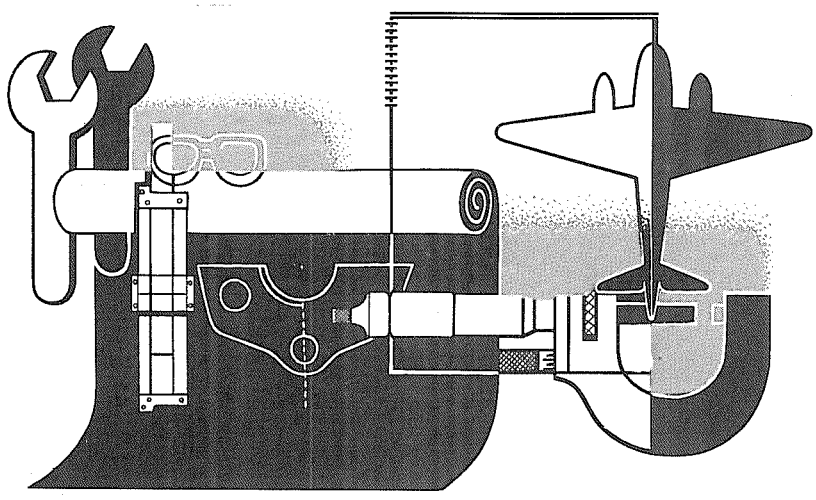


INTRODUCTION

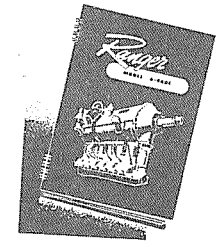
This manual is written to supply the information necessary for the complete overhaul of the Ranger Model 6-440C engines. Every different type of engine will present problems which are unfamiliar even to skilled mechanics. It is, therefore, recommended that anyone having occasion to overhaul this type of engine make a thorough study of this manual and keep it available for handy reference while performing the work. The manual covers every step necessary in the process of overhaul but particular emphasis has been placed upon operations which, in the opinion of the manufacturer, warrant special attention.

The various chapters of the manual have been divided in such a way as to make it most practical for shop use. Recommended shop practices and operations which apply to various sections of the engine have been grouped together in the first chapter to avoid repetition. The complete disassembly of the engine, inspection, repair, reassembly and testing procedures, as well as packing instructions, are covered in individual chapters. Oil diagrams and limits charts will be found in the back of the manual and should be consulted frequently.

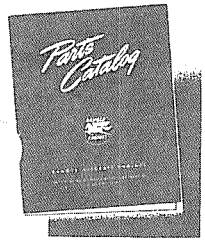
The following definitions have been used throughout the manual: The propeller end of the engine is the "Front" and the anti-propeller end is the "Rear." The "Right" and "Left" sides of the engine are referred to as viewed from the rear, with the engine in the normal position. The "Normal" position of the engine is its position in normal level flight. The "Inverted" position is the position of the engine in inverted flight or upside down.

Cylinders, pistons, etc., are numbered from 1 to 6, starting at the rear cylinder.

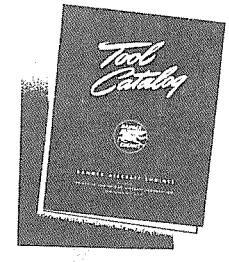
In addition to this overhaul manual, the following publications covering the Ranger Model 6-440C engines are available:



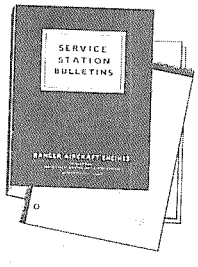
Instruction Handbook. This book contains information for pilots and maintenance mechanics. It gives complete operating instructions as well as outlines of inspection procedure and minor repairs.



Parts Catalog. This publication lists all parts by name and part number. Parts are listed numerically and by assemblies. All parts are illustrated and special notes refer to interchangeability between models. A separate section describes oversize replacement parts. Supplements are issued from time to time to keep the parts list up to date.

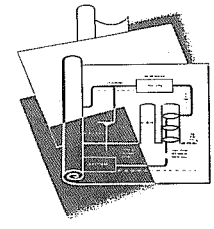


Tool Catalog. This publication lists all special tools required for the complete overhaul and repair of 6-440C engines.



Service Bulletins. These bulletins are issued whenever necessary to inform operators of important changes. Complete sets of Service Bulletins are available to approved overhaul shops and other responsible agencies. Holders of Service Bulletins will be placed on the mailing list for subsequent releases if such service is requested.

Wall Charts. Charts of oil diagrams and clearance charts, similar to those shown in Chapter IX of this manual, as well as line drawings showing exploded views of all sub-assemblies, are available for shop and school use.



Operators are invited to contact the Service Division of Ranger Aircraft Engines with any problems concerning the overhaul, servicing and operation of their engines which are not covered in this manual.

Table of Engine Model Designations

RANGER DESIGNATION	6-440C-2	6-440C-2	6-440C-3
ARMY DESIGNATION	L-440-1	L-440-9	——
NAVY DESIGNATION	——	——	——
HORSEPOWER	175	175	180
COMPRESSION RATIO	6:1	6:1	6.2:1
FUEL OCTANE RATING	65	65	73
CARBURETOR	Stromberg	Stromberg	Stromberg
ID OF INTAKE PIPES	1.686″	1.686″	1.561″
MAGNETO	Scintilla	Edison	Scintilla
SPARK ADVANCE	22°	22°	25°
IGNITION HARNESS	Plain	Plain	Plain

Except for differences listed below, all 6-440C engines are identical in construction. These differences do not affect the method of overhaul and are given only for purposes of identification.

6-440C-4	6-440C-5	6-440C-5	6-440C-5	6-440C-5
———	L-440-3	L-440-5	L-440-7	L-440-11
———	———	L-440-2	———	———
190	200	200	200	200
6.8:1	7.5:1	7.5:1	7.5:1	7.5:1
80	87	87	87	87
Stromberg	Marvel- Schebler	Stromberg	Marvel- Schebler	Marvel- Schebler
1.561″	1.686″	1.561″	1.686″	1.686″
Scintilla	Scintilla	Scintilla	Scintilla	Edison
25°	25°	25°	25°	25°
Plain	Shielded	Shielded	Shielded	Shielded

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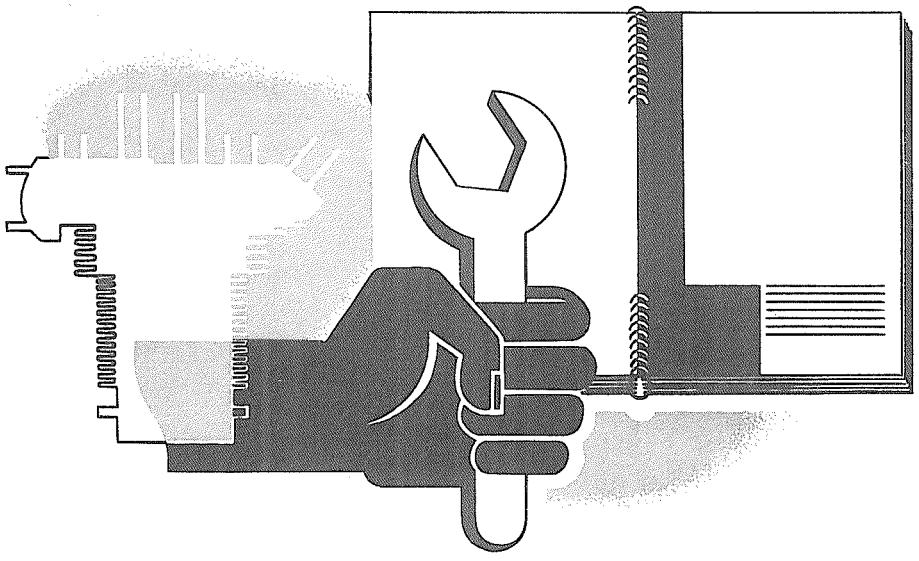


GENERAL OVERHAUL INSTRUCTIONS

The major overhaul of an engine consists of the following operations: Disassembly of the engine and all of its sub-assemblies, cleaning of all parts, complete inspection of all parts, the replacement, repair or reconditioning of worn or damaged parts and the complete reassembly of the engine. Specific instructions concerning all of these operations are given in that part of the manual covering the particular engine parts to which they apply. However, there are certain general practices which apply to all parts or to the engine in general. Recommendations concerning such general practices have been grouped together in this chapter.

One of the most important requirements for the satisfactory overhaul of an engine is to have shop space of sufficient size which is free of dust, dirt and excessive moisture and is equipped with adequate lighting and ventilating facilities. In addition to the special tools required for the overhaul of Ranger 6-440C engines, the following general shop equipment is necessary: A chain hoist, bench lathe, drill press, arbor press, valve grinding machine, valve seat grinder, bench grinders, cylinder grinder and cylinder hone; also pressure spray booths for the cleaning, painting, sandblasting and metallizing of engine parts, chemical tanks for cleaning, degreasing and plating and complete inspection facilities.

Inspection equipment should include a magnaflux machine, surface plate, inside and outside micrometers, telescope gages, depth gages, stretch gages, cylinder diameter gages, spring pressure gages and certain

special measuring tools which are fully described in the chapter covering inspection of the parts for which they are used.

An adequate record system is a necessary part of every overhaul. Special forms should be used to record the condition of an engine upon arrival. An overhaul inspection form should be used to record the condition of all parts of the engine so that a record can be kept of the parts replacements in each engine at every overhaul. This form should also be used to record clearances and the physical dimensions of certain parts as they are installed in the engine. Such a form also serves as a check-off list to the inspector during inspection and reassembly and reduces the possibility of overlooking any important steps in the overhaul of the engine. Suggested forms for use with the 6-440C engines are shown in chapter VIII of this manual.

DISMANTLING AND DISASSEMBLY

This section includes information for the complete dismantling and disassembly of the engine into its component parts, covering only such inspections as should, and can best be made during the disassembly procedure.

Before dismantling, the exterior of the engine should be thoroughly cleaned with an approved cleaning solution, preferably safety naptha under air pressure. All external parts should then be wiped dry with clean lintless cloths. Cleaning of the engine should be done in a specially constructed spraying booth with approved equipment.

During the various stages of dismantling, all parts should be checked closely for signs of scoring, burning or excessive wear. Many valuable indications of defects can be obtained when oil, carbon or the loosened surface of the metal are present to indicate them. After all parts have been washed, some of the evidence of malfunctioning may have been destroyed.

Special Equipment

Before starting to disassemble the engine, make sure that the following equipment or its equivalent is on hand:

Lifting Sling, AT-183, and Lifting Eye, AT-120, for use on engines not equipped with a crankcase lifting eye. If this special sling is not available, a long cable sling may be used by passing the cable through the lifting eye in the generator cover plate at the rear of the engine and around the propeller shaft at the front end. Care should be taken not to damage the propeller shaft or nose section. For engines equipped with a crankcase lifting eye, no sling is required.

Engine Assembly Stand, AT-182. Use of this stand enables inverting the engine without removal from the stand.

To properly disassemble the engine, a standard type work bench and an Engine Parts Rack, AT-184, are necessary.

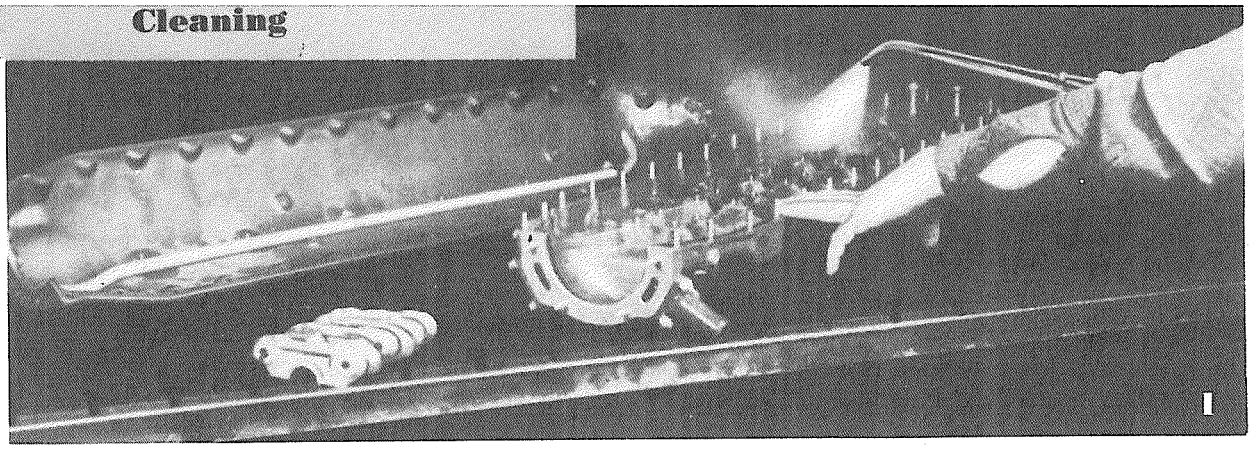
The engine parts rack should be equipped with special small racks to carry valves, gears, shafts, etc. They will keep these parts from being damaged when coming in contact with each other and will also prevent parts such as valves which are not individually identified from becoming mixed up.

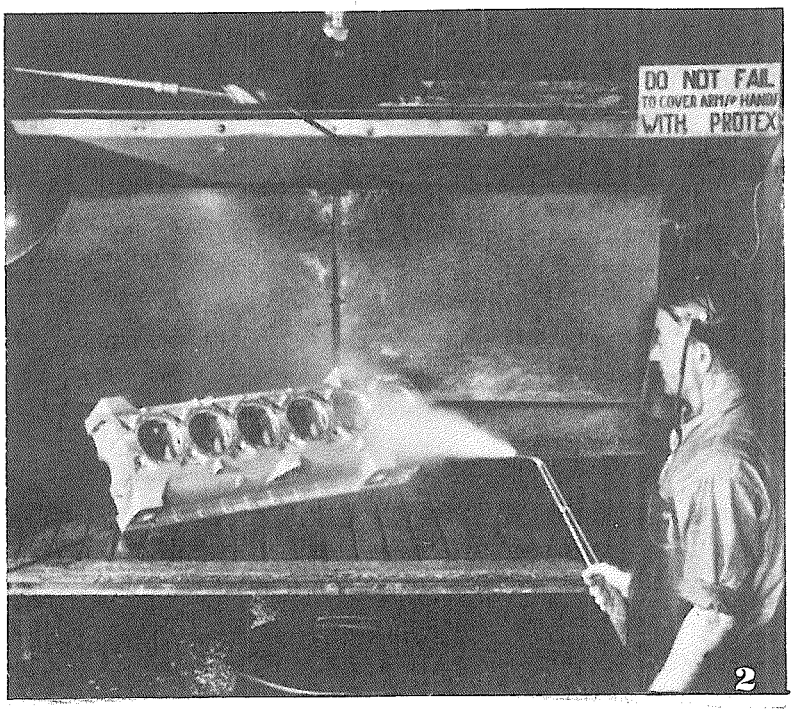
When removing unmarked major parts, make sure that each one is clearly numbered or tagged with regard to its exact location on the engine and its position with respect to adjacent parts.

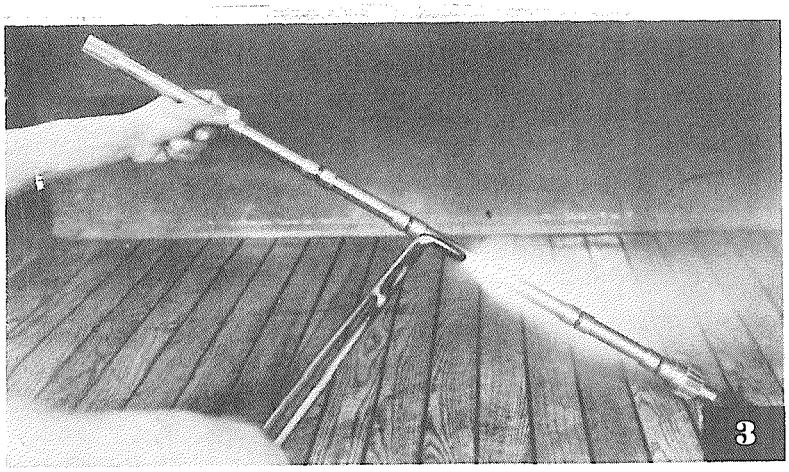
When removing nuts safetied with locknuts (commonly known as palnuts) always loosen and remove the locknut before loosening the plain nut. Do not attempt to loosen or tighten the two nuts at the same time.

Cover all accessory pad openings, spark plug holes, etc. with suitable covers or plugs to prevent dirt or other foreign material from getting into the engine.

Additional special tools for the complete dismantling and inspection of the engine are listed in Chapter VIII of this manual.







CLEANING

Certain parts of the engine, such as gaskets, oil seals, oil retainers and hoses are discarded at every overhaul. All other parts must be cleaned as soon as possible after the dismantling of the engine. The first step in cleaning engine parts is to remove all traces of oil with a solvent spray and a stiff brush where necessary. 1

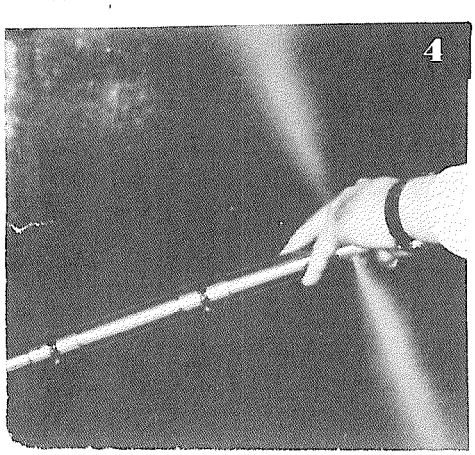
The solvent spray used for this operation should be in the nature of a safety naphtha. A list of commercial solvents suitable for this purpose is given in Chapter VIII. Parts should be cleaned in a special spray booth in which the parts are supported on a wooden platform at bench height, and which has adequate provision for ventilation and drainage. 2

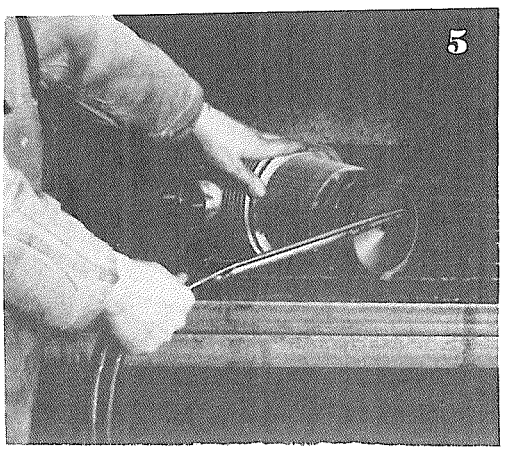
All parts of the engine should be sprayed externally. 3

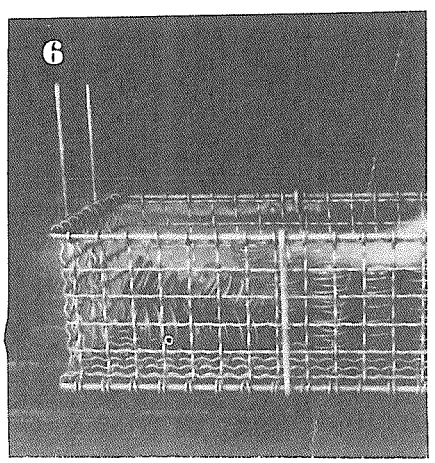
Hollow parts should also be sprayed on the inside. 4

This applies particularly to oil passages in hollow shafts and in castings. Engine parts which have pockets or recesses in which oil and dirt might accumulate, such as between closely spaced cylinder fins, must be cleaned with particular care by directing the spray into the various corners. 5

Small parts, such as valve springs, which are difficult to hold under the spray, may be cleaned together in a wire basket. . . . 6



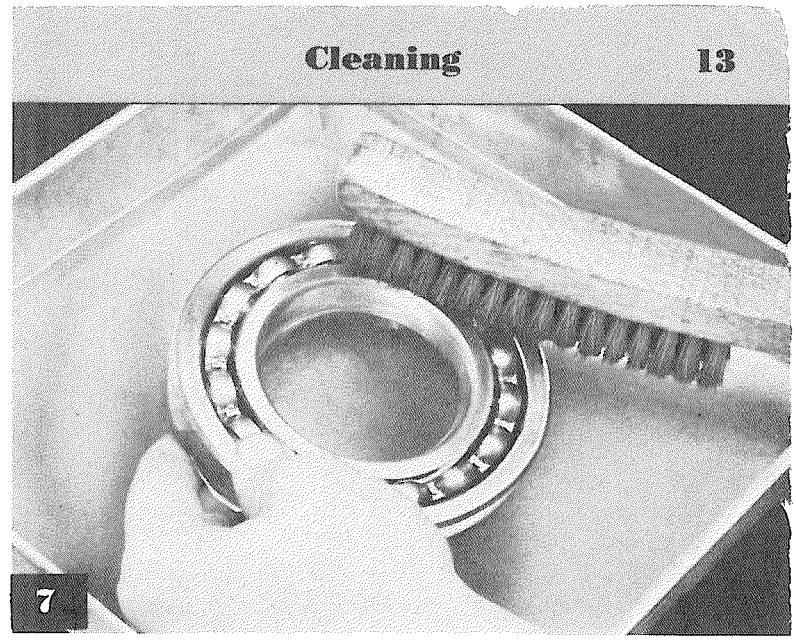




However, in doing this care must be taken to arrange the parts in such a way that they will not be damaged by striking against each other.

Ball and roller bearings should not be cleaned in the solvent spray but should be immersed in a pan of clean solvent. . . . . **7** Brush the bearing with a clean soft brush in good condition to remove all traces of dirty oil and sludge. When the bearing is clean, it should be dried off with compressed air without allowing the dry bearing to spin. After this, each bearing should be dipped in light engine oil and then wrapped in oiled paper immediately.

Parts which cannot be completely cleaned by spraying should be cleaned with some approved type of chemical carbon remover. A list of such chemicals is given in Chapter VIII. The chemical may be either in the form of a vapor to which the parts are exposed, or in the form of a liquid which may be used either as a bath or with a brush. The chemical properties of available engine cleaning compounds vary widely and the manufacturer's recommendations must be followed closely in determining the proper cleaning procedure. Nearly all chemical engine cleaners are injurious to the skin and mechanics should avoid exposure to them by covering their hands with some type of protective coating or by wearing rubber gloves. The former method is preferred because the presence of a chemical which has penetrated a rubber glove cannot be felt until the skin is affected. Steel parts can be cleaned with almost any type of cleaner. However, if such steel parts are cadmium plated, the same precautions must be observed as for aluminum, as the plating will otherwise be destroyed.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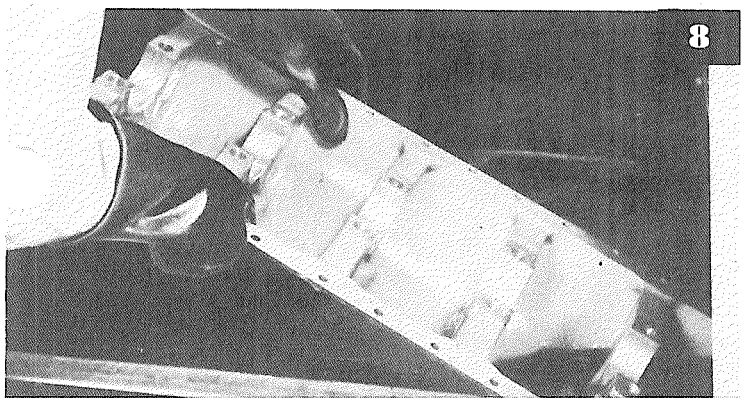
Aluminum and magnesium alloys may not be cleaned with hot caustics due to the strong corrosive action. Alkaline solutions and soap compounds should not be used for aluminum and magnesium because these cleaners cannot be rinsed from the pores of these metals. Most other commonly available cleaners can be used, provided certain precautions are observed. The most important rule is not to leave such parts exposed for too long a time. Certain chemicals cannot be used full strength to clean aluminum or magnesium while others are harmless provided no water is present in the chemical mixture.

Main and connecting rod bearings should be cleaned only in a solvent spray, but should not be exposed to strong chemicals and should not be cleaned by brushing or scraping.

The conventional method for cleaning carbon from most other engine parts is to submerge them in the chemical cleaner tank for a long enough period to remove the carbon without affecting the material or the finish of the part. . . . . **8** After this, all parts are cleaned with the solvent spray. **9**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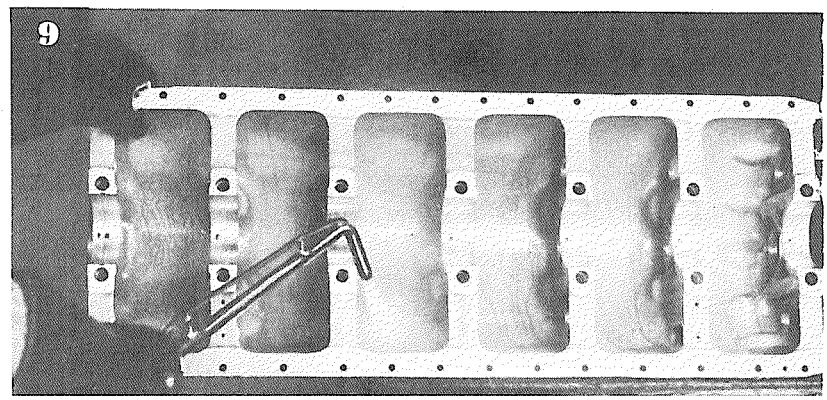
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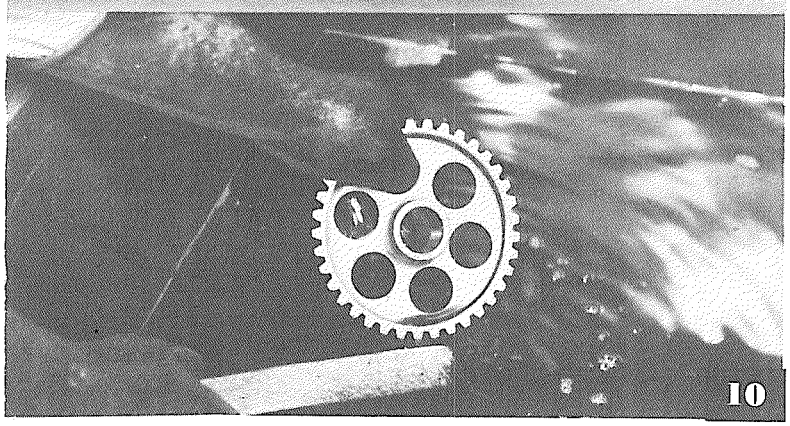

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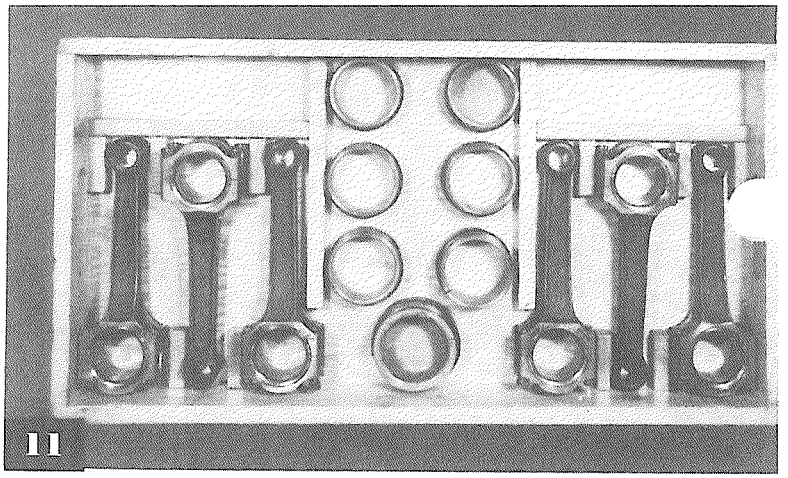


11

Any parts which still show carbon deposits should be brushed with a chemical cleaner and a stiff brush to loosen the carbon. . **10** After this, they must again be rinsed with the solvent spray.

Where carbon deposits are so heavy that they cannot be removed by chemical action alone, they may be removed by scraping, but care must be taken so that the part is not scratched. In certain locations, such as inside the piston, carbon deposits may be removed with a rotary wire brush or by sandblasting. Since sandblasting is also an essential part of the metallizing procedure, it is described in the section on refinishing.

Where the condition of painted surfaces of an engine make it advisable, complete stripping of all paint can usually be accomplished by a longer period of exposure to the same chemical as was used to remove carbon. However, since such exposure might affect the metal itself, the use of special stripping compounds is preferred. Trichlorethylene vapor will strip paint without adverse effect on the metal itself. Certain other chemical cleaners which contain phenol will also remove paint without damage to the metal, provided the exposure is limited. Suitable paint stripping compounds are listed in Chapter VIII.

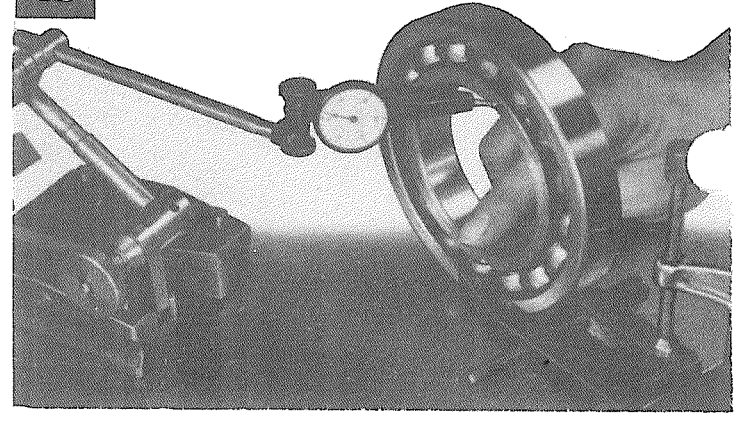
Unless they are to be inspected immediately, all steel parts must be covered with a coat of rust preventive oil, either by spraying or in a dip tank, as soon as they have been cleaned. At no time should a steel part be allowed to remain dry for more than two hours. The cleaned and oiled parts should be placed on the Engine Parts Rack, AT-184, in such a manner that they cannot become damaged by contact with each other.

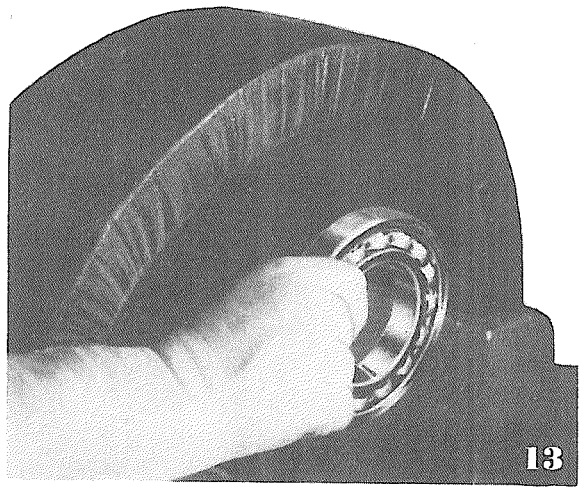
Delicate parts such as main and connecting rod bearings should be separated from the other parts and placed in specially designed boxes. **11**

INSPECTION AND REPAIR
Anti–Friction Bearings

Anti-friction bearings are made to extremely close tolerances and require special treatment to prevent foreign matter from entering the bearing. Such bearings should be wrapped in oiled paper immediately after they are removed from the engine and should remain wrapped until they are to be cleaned. After the bearings have been cleaned, they should be oiled with light engine oil. A common test of an anti-friction bearing is to spin it and to listen for chatter or roughness. While this method may be found satisfactory in most cases, it requires considerable experience and leaves much to the individual judgment of the inspector. A more accurate test for roller bearings is to clamp the outer race to a surface plate and to check the end play of the inner race by moving its upper edge back and forth by hand. The actual amount of free movement of the inner race can be checked with a dial indicator and can then be checked against the replacement limits given in the Table of Limits. **12**

12

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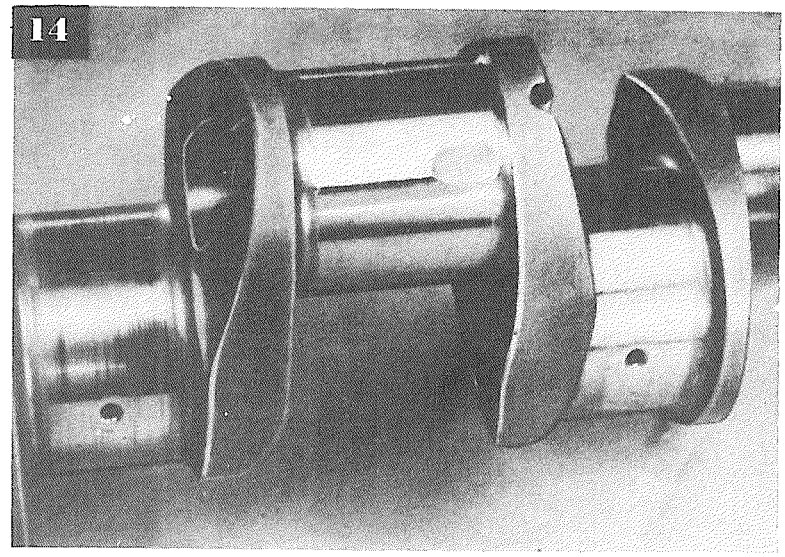
Anti-friction bearings should, under no circumstances, be inspected by the magnaflux method as the iron powder in the liquid which enters the bearings can never be completely cleaned out. On the other hand, anti-friction bearings should be demagnetized at each overhaul to prevent the possibility of any small steel particles in the oil stream being attracted by the bearings. **13**

In general, anti-friction bearings cannot be reworked or repaired. However, slight galling or roughness on the outside of the race may be cleaned up by light stoning and polishing.

Gears and Shafts

Because of the high local stresses to which they are subjected, all gears should be inspected with the greatest care. Actual cracks at the base of the gear teeth and ir the corners of the splines can be determined by magnaflux inspection as described in Chapter III. In addition, the teeth and splines should be examined very carefully for signs of roughness, pitting or excessive wear. Slight nicks, which may have been caused by coming in contact with other engine parts during disassembly, should be cleaned up by stoning. Slightly pitted gear teeth should also be cleaned up, but the gear must be discarded if the pitting extends so far below the surface that it cannot be stoned out without seriously affecting the contour of the teeth. Whenever a gear is discarded because of wear, the mating gear should be examined very carefully to determine whether it has been affected by the same condition. Whenever the front end bevel gears show signs of excessive wear, determine whether they are of the correct thickness.

Nicks and scratches in all other steel parts, such as cylinder barrels, crankshafts, valves, etc. can, in most cases, be cleaned up by stoning if the condition is not too serious. The two major considerations in deciding whether a part can be stoned are whether removal of the materials will affect the strength of the part and whether the change in the shape of the part will cause increased wear on other parts. The most important thing to remember in reworking parts is to avoid making sharp corners or rapid changes in cross sections which might cause high localized stresses. Nicks and magnaflux indications on shaft journals may be stoned out, even to the point where a small flat spot is left on the journal. . . **14** However, such a flat spot may not fall at the edge of the bearing as it might cause loss of oil pressure. **15**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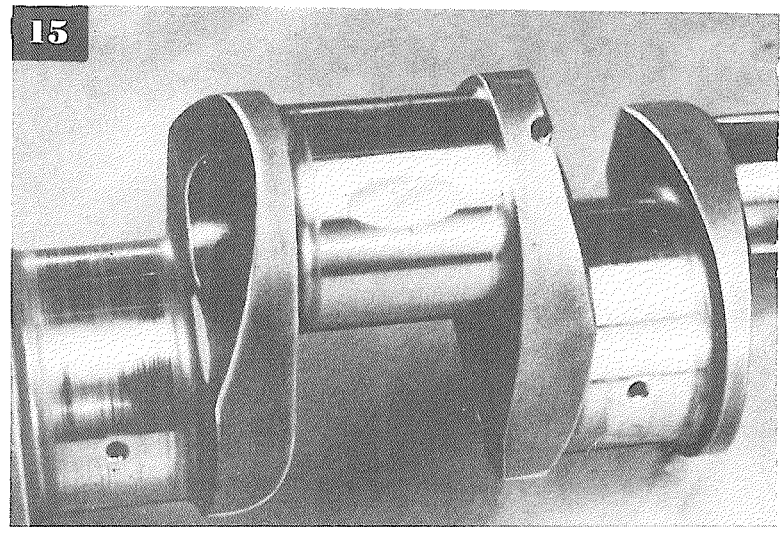
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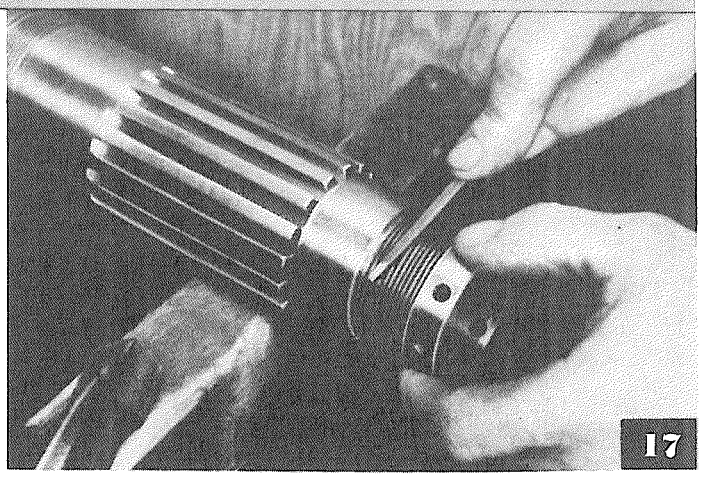
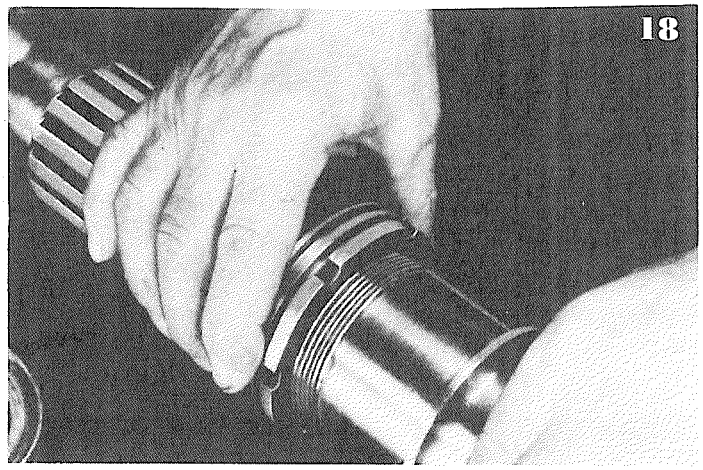
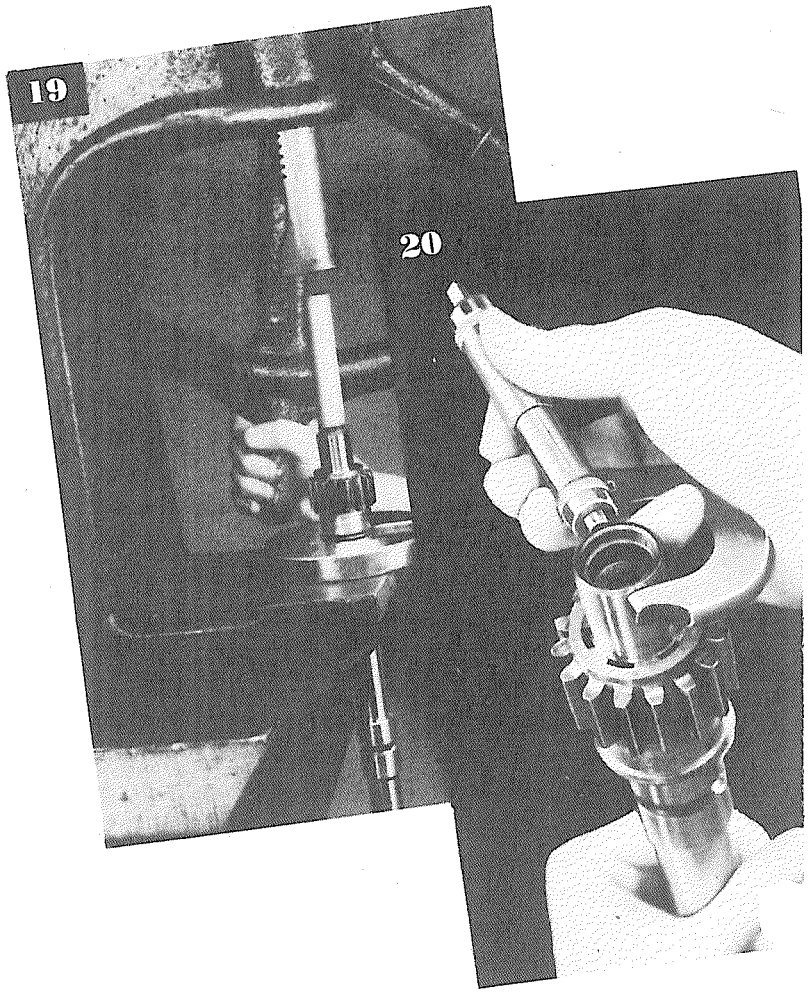




Rough threads on a steel shaft may be smoothed off with a file shaped to fit the grooves of the thread. **17**
After this operation, the nut which fits on this thread should be coated with fine lapping compound. The nut should then be lapped on the thread on the shaft. . . **18**
Where cup plugs have to be replaced in the ends of shafts, they should be pressed in place in an arbor press in preference to being tapped into position with a hammer. **19**
The diameter of the shaft at the location where the plug is installed should be measured with a micrometer both before and after installation. **20**
If the shaft is found to have expanded as a result of pressing the plug into position, the shaft must be ground or lapped so that the clearance between the shaft and the bushing will not be less than the minimum given in the Table of Limits.

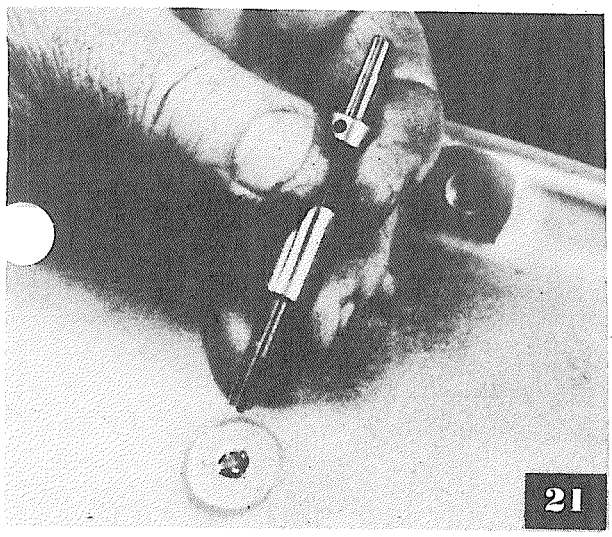


Castings

Nicks and scratches in machined surfaces of aluminum and magnesium parts may be blended into adjacent areas with a file and stone. The most important consideration is to smooth off any sharp corners. Where nicks and cracks extend across a parting surface, the surface may not be filed in such a way that a groove extends across its entire width as this would cause an oil leak.

Where traces of corrosion are found on aluminum and magnesium alloy, the affected areas must be cleaned of all traces of corrosion with a rotary file. This method can also be used to smooth off sharp edges or to remove metal in order to eliminate interference between parts.

Wherever a bare magnesium surface is exposed as a result of filing, lapping, cutting or stoning, it must be immediately protected by brushing with sodium dichromate ($Na_2 Cr_2 O_7 2H_2O$).



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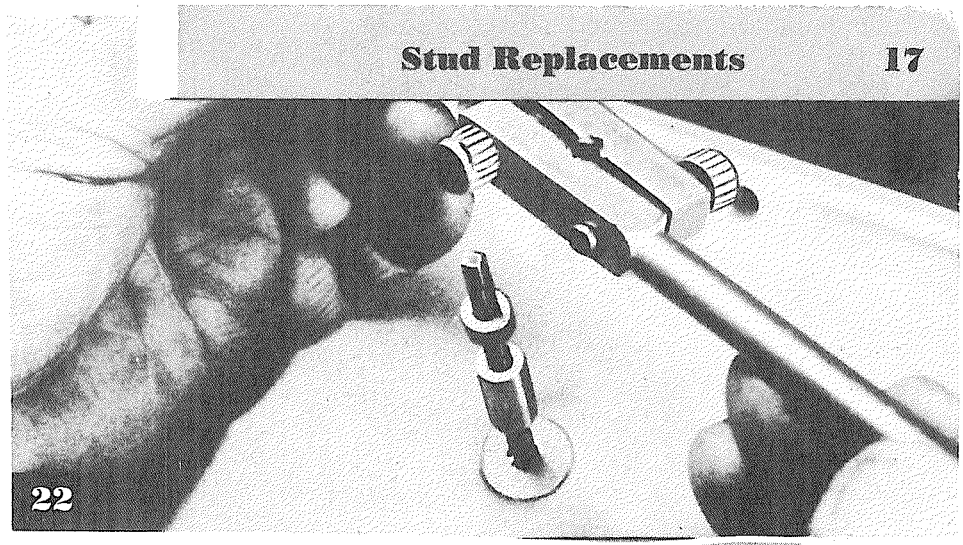

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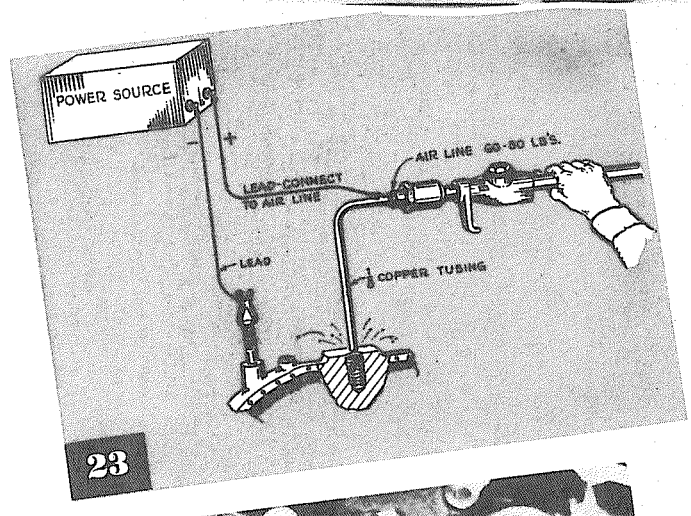
Studs

Broken studs, dowels or taps may be removed with a conventional screw extractor. . . . . .**21** and **22**
Another method is to use an Etchograph machine which burns out the broken end with an electric arc directed into the hole under air pressure. **23**
For this operation, attach the ground connection as close as possible to the part to be burned out. **24**
If this device is skillfully handled, it is possible to remove almost the entire stud without injury to the threads in the casting.

Whenever a defective stud is removed from a casting, the original hole will be oversize so that a standard stud cannot again be installed. Studs are available in oversizes of +.003″, +.006″ and +.009″. These studs may be identified by the different shape of the end which enters the casting. The +.003″ stud has a pointed end, the +.006″ has a countersunk end, and the +.009″ has a hole drilled 3/32 of an inch deep in the end. **25**
Select the oversize which will make a tight fit in the hole, but not so tight that there is danger of splitting the casting.

In cases where the original stud has pulled out and damaged the thread in the casting to the point where even the largest oversize stud is loose, step studs are available. The diameter of that portion of a step stud which enters the casting is about .060″ larger than that of the original stud. Where a step stud has to be installed, first drill out the original hole to the correct size for the thread of the step stud and then tap a new thread of the correct size.



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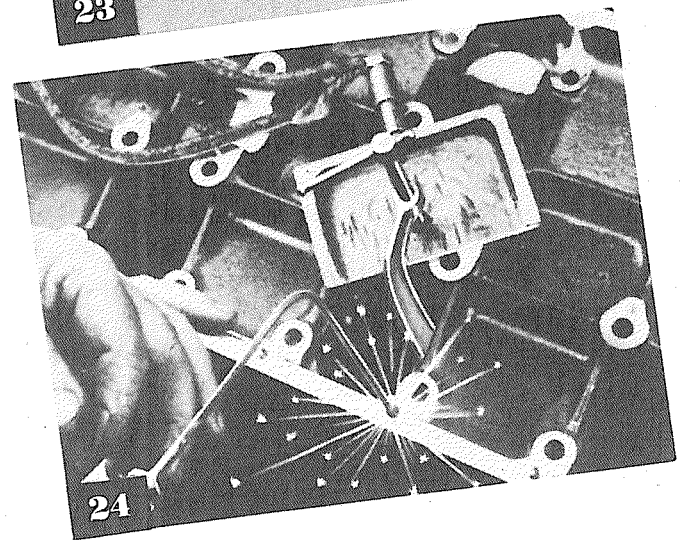

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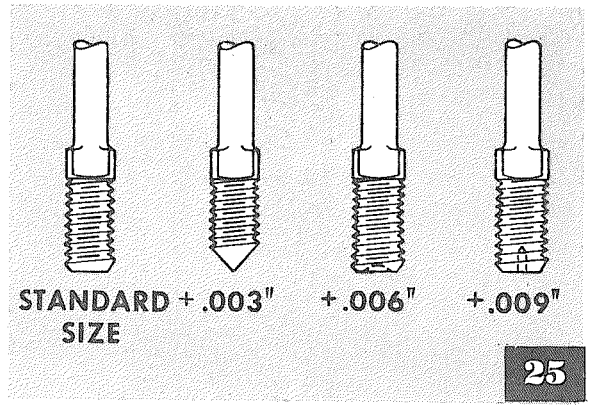

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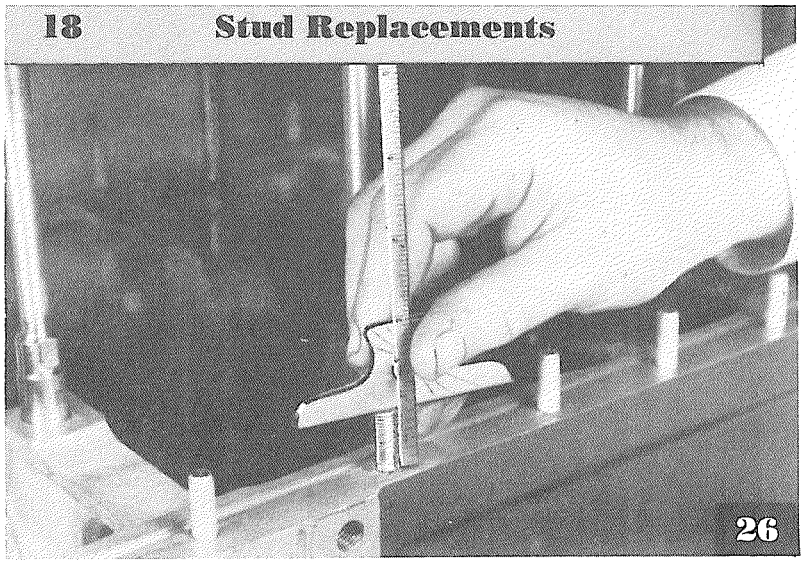
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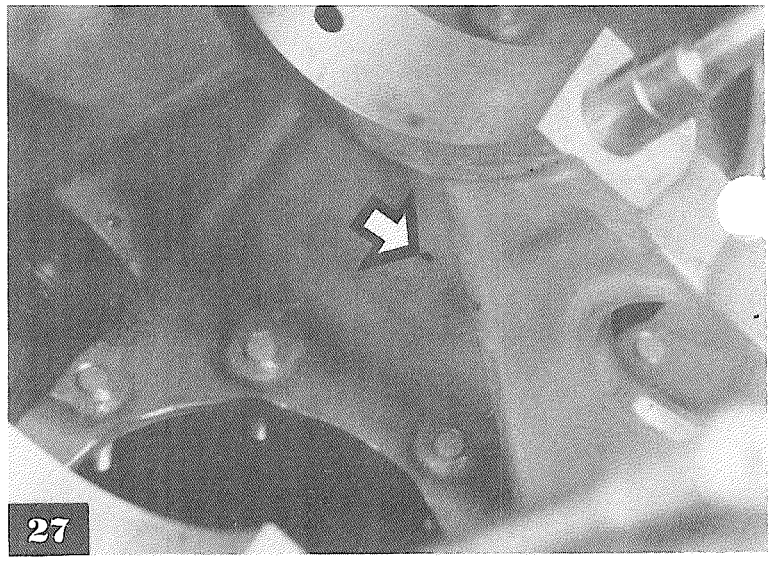
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Select the proper tool for installing each particular size of stud from the following list:

AT-233 Driver—MainBearing Stud

AT-234 Driver—Necked Cylinder Head Stud

AT-235 Driver—Screw Bushing (Used to install screw bushing in rear of camshaft housing cover.)

AT-238 Handle—Ratchet (Use with AT-234 and AT-235.)

AT-594 Kit—Driver { (¼-28 Stud; (5/16-24 Stud; (⅜-24 Stud

Drive the new stud to the same depth as the old stud. Check this by measuring the free length of the stud with a depth gage. **26**

When installing main bearing studs, make sure that the small vent hole in the web of the lower main crankcase half is open. . **27**

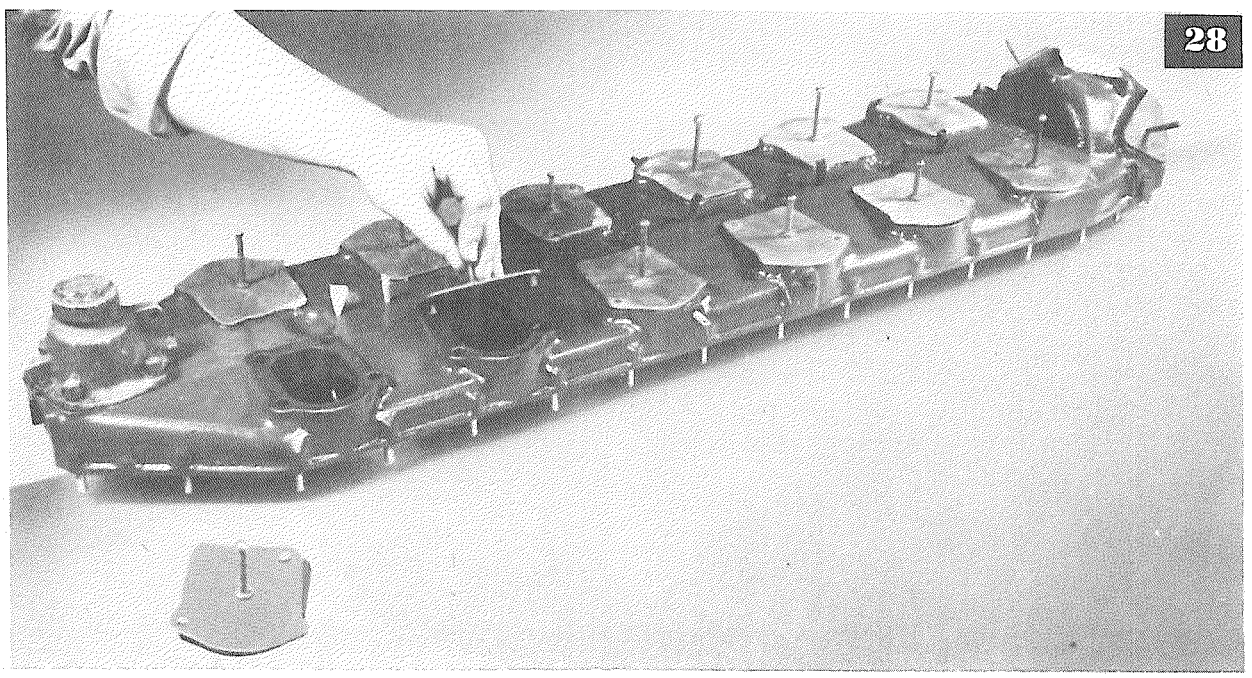
If these holes are plugged by carbon or other obstructions, the crankcase web may be cracked by the pressure of oil trapped in the stud hole.

REFINISHING

Painting

Where the paint on a part has become dull, rough or scratched, but is not bad enough to warrant stripping, the part can be refinished as follows:

1. Wash the part in a mixture of gasoline and carbon tetrachloride.
2. Sand paper the original paint, especially around rough or chipped areas, until a smooth surface is obtained.
3. Dust off the part with dry compressed air.
4. Protect all machined surfaces with special covers. **28**
   Masking tape may be used if these are not available.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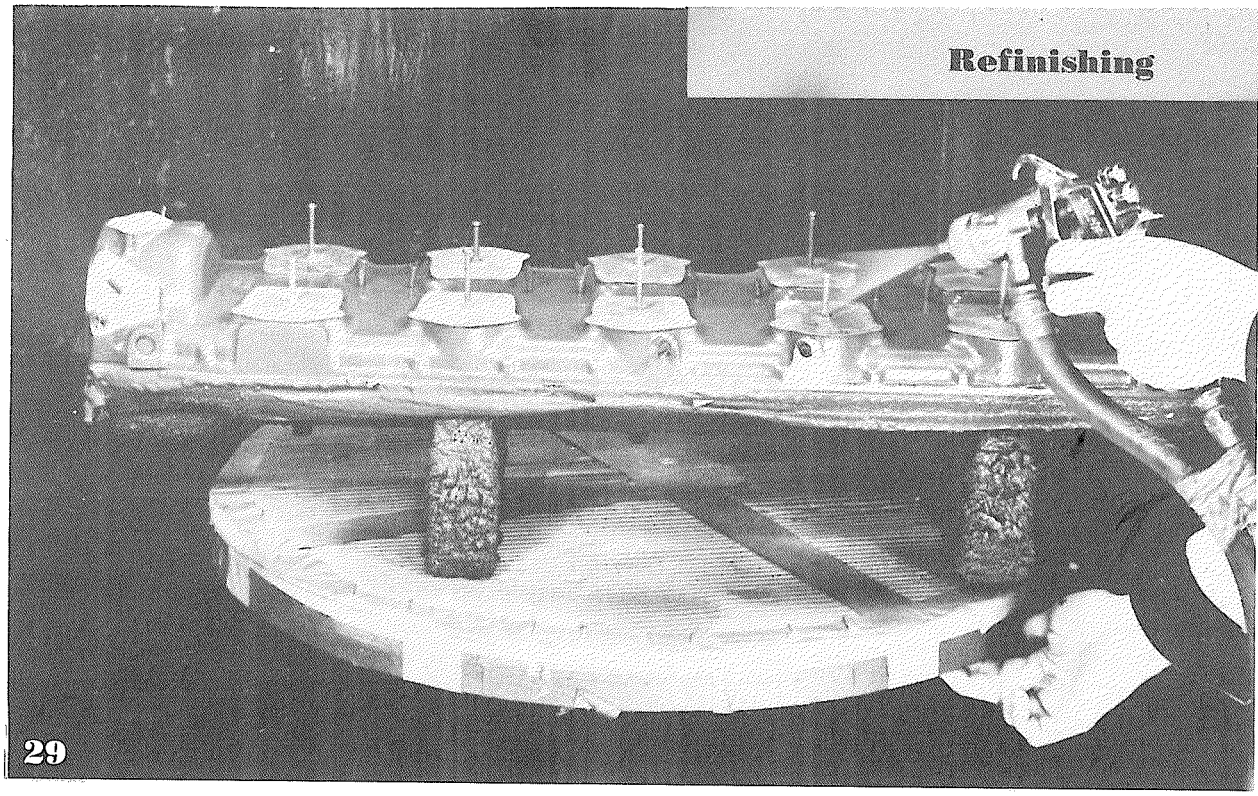
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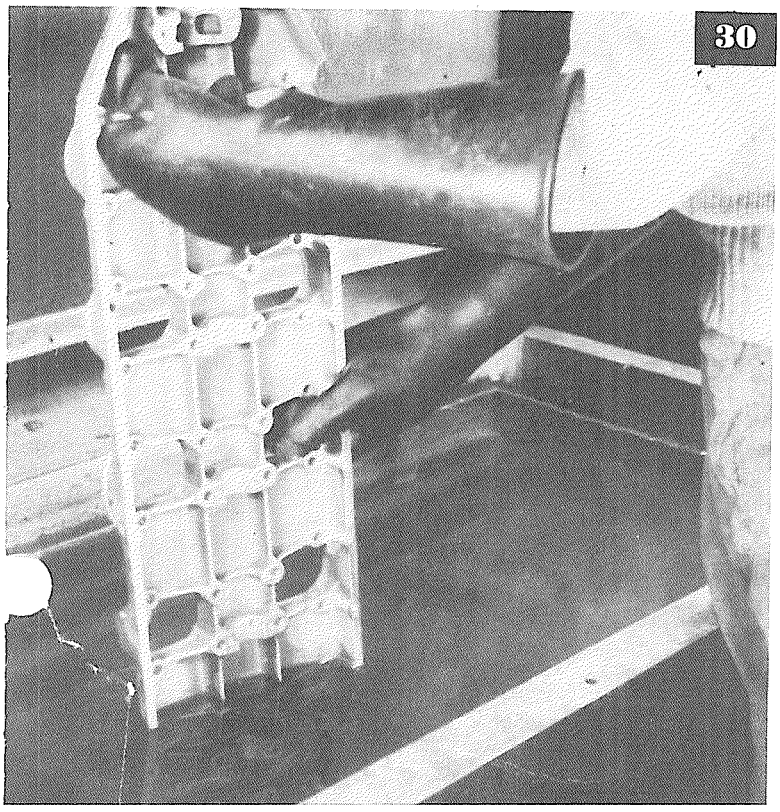
5. Spray on one coat of grey phthalate enamel, Ranger Specification E-5-E. 29
6. Bake in a flameless oven at 250° F. for a period of two hours.

Where the finish on a magnesium alloy part has been chipped or scratched to the extent that complete repainting is necessary, proceed as follows:

1. Strip all of the old paint by sandblasting or immersion in a paint stripping solution. In doing this, care must be taken not to leave the part exposed so long that the solution will attack the metal.
2. Remove all traces of dirt by cleaning with a solvent spray.
3. Wash the part thoroughly in hot running water. 30
4. Apply cold sodium dichromate with a brush, being careful that the dichromate does not touch the studs as it will affect the cadmium plating. 31
5. Rinse in cold water and then dip in hot water.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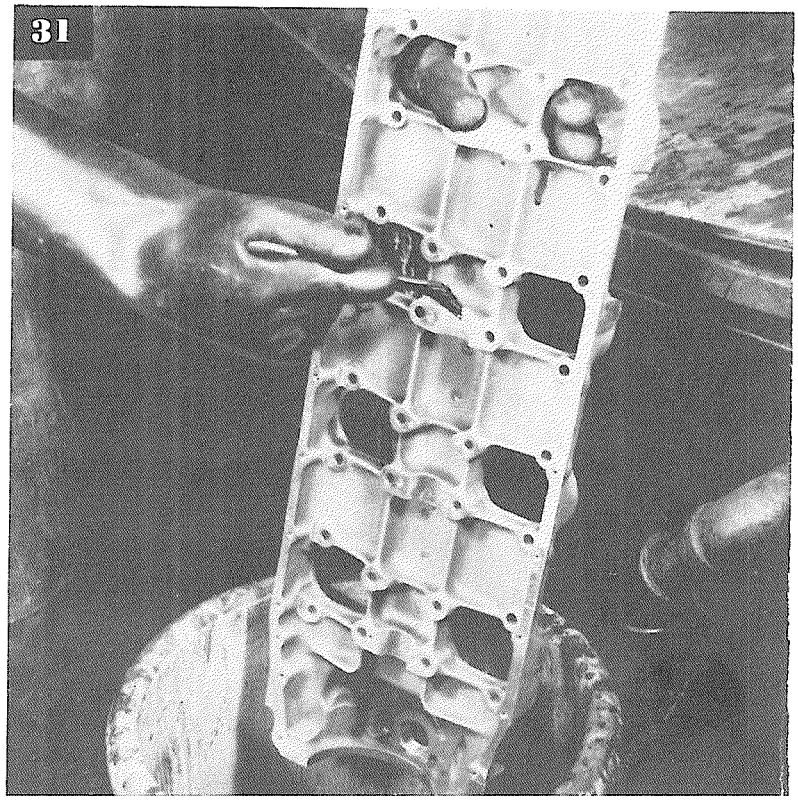
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6. Dry rapidly with compressed air.
7. Apply one coat of zinc chromate primer with a spray gun and air dry.
8. Spray on three coats of grey phthalate enamel, baking each coat in a flameless oven for one to one and one-half hours at 300° F.

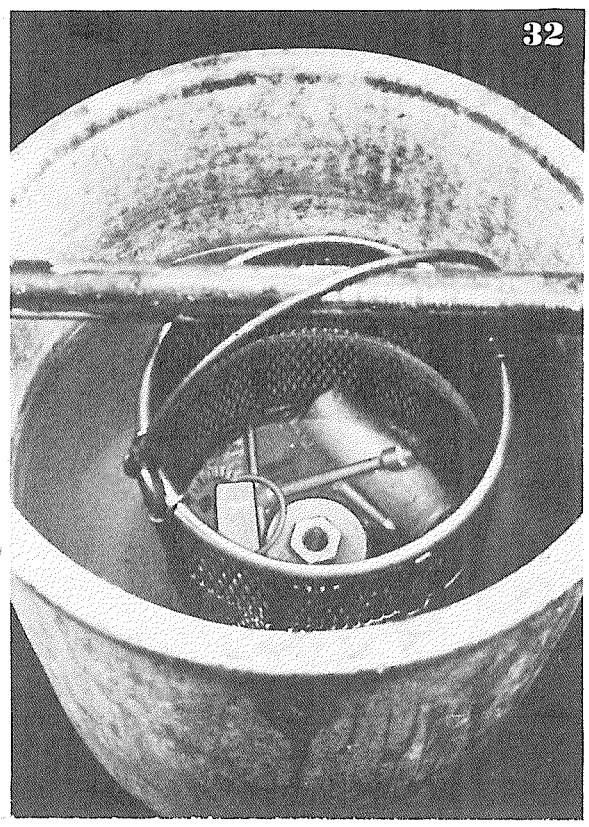
If an aluminum part requires complete repainting, proceed as follows:

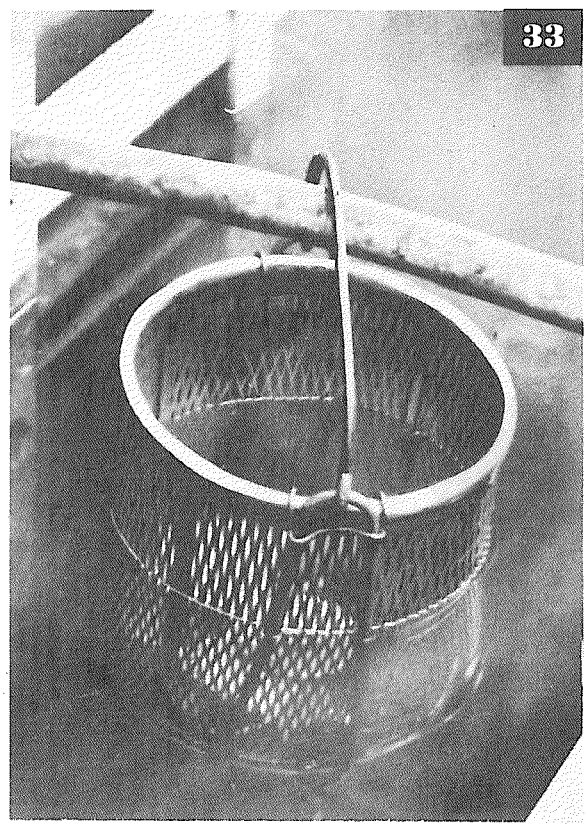
1. Strip the original coat of paint, chemically or by sandblasting.
2. Clean off all traces of dirt with a solvent spray.
3. Wash thoroughly in hot running water.
4. Dry with compressed air.
5. Spray on one coat of zinc chromate primer.
6. Apply two coats of grey phthalate enamel and bake each coat for two hours at a temperature of 280° F.

Cadmium Plating

All exterior parts made of steel or brass, such as cylinder head baffles, vertical drive shaft housing, washers, hose clamps, pipe plugs and all types of nuts except self-locking nuts with a fiber insert, are cadmium plated as a protection against corrosion. Since the thickness of cadmium plating is normally less than .001", it is easily scratched in service and during disassembly. It is therefore recommended that all parts be replated with cadmium at overhaul. The procedure is as follows:

1. Degrease the parts to be plated by placing them on a wire tray above a solution of trichlorethylene heated by steam pipes. The vapor formed by the heat rises past the cylinders and removes the grease. It is then condensed on cold water pipes running through the top of the tank and the condensate runs back into the tank below.
2. Strip the parts by immersion in a solution of amonium nitrate or muriatic acid for about 30 minutes. **32**
3. Soak the parts in a solution of caustic soda for 30 minutes. . . . . **33** The formula for this mixture is given in Chapter VIII.
4. Place all parts to be plated in a tank containing the cadmium plating solution, the formula for which is given in Chapter VIII. Large parts will have to be suspended individually on wires. All small parts, such as nuts, washers, pipe plugs, etc., are placed in a tumbler which keeps the parts in motion during the plating process so that they become evenly coated.
5. Plating is done by direct current.



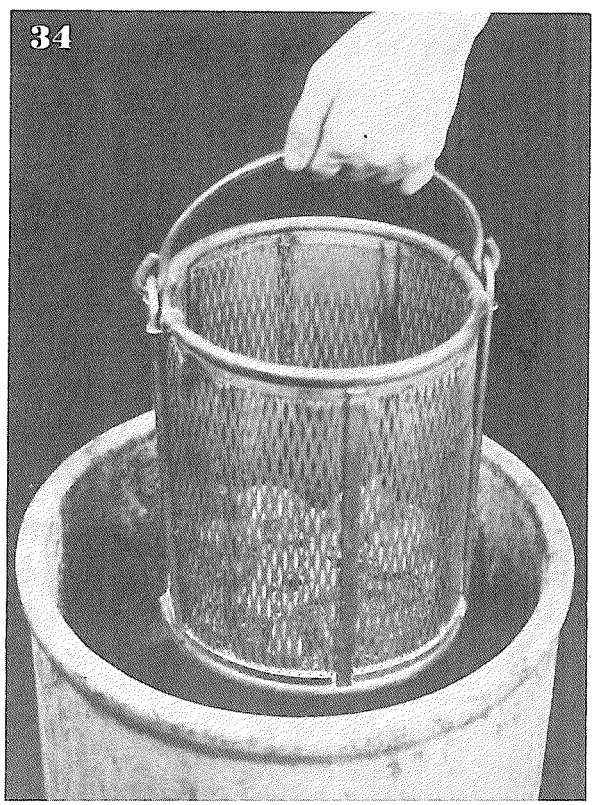


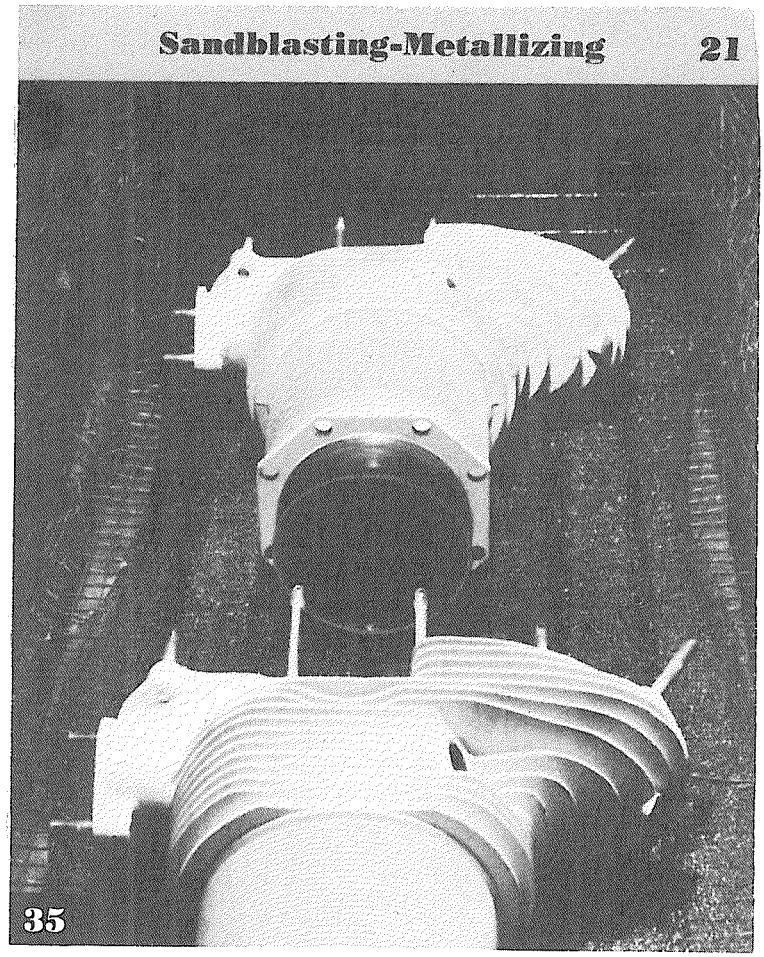
The parts to be plated are connected to the negative wire, and bars of pure cadmium suspended in the solution are connected to the positive wire. The current required depends on the size of the tank and the number and size of the parts which are to be exposed to the current. The time and current required to cadmium plate to a certain thickness varies with each individual installation. The coating should vary in thickness from .0005″ for the cylinder head baffles, to .00025″ for vertical drive shaft housings, nuts, washers and most other parts.

6. After removal from the plating tank, bright dip the parts in water containing 1% nitric acid. **34**

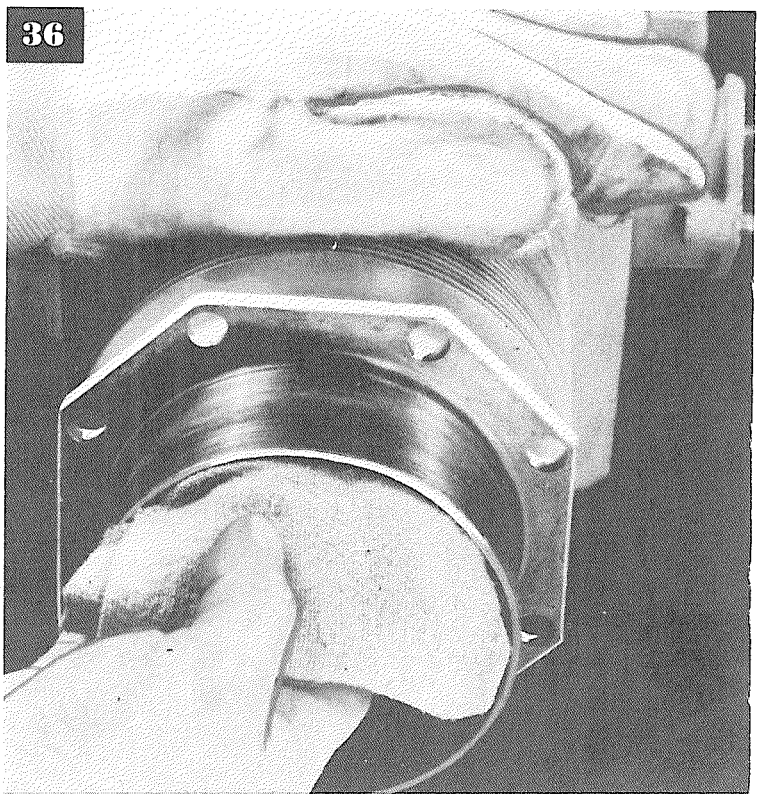
Sandblasting and Metallizing

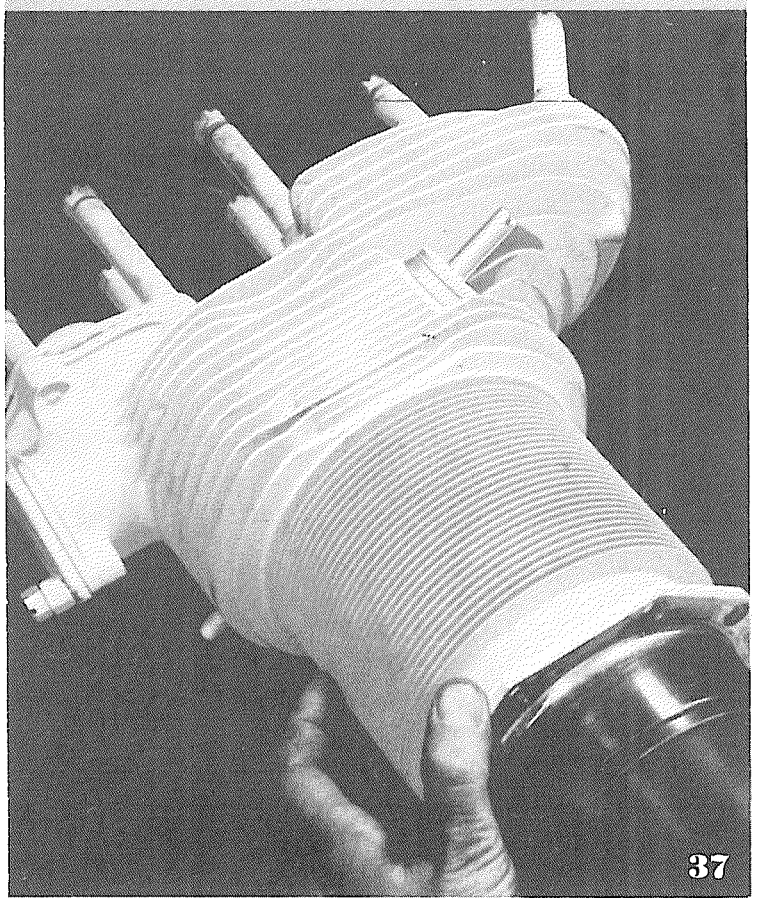
Unsatisfactory metallizing on cylinders is indicated by rust on the fins or by flaking off of the alumium coating. However, the absence of these indications is no positive proof that the metallizing is in good condition and, in general, it is recommended that cylinders be remetallized at each overhaul. To prepare the parts for metallizing, they must first be degreased and then sandblasted.





Completely degrease the cylinders with trichlorethylene vapor. **35**
As soon as the cylinders are completely cleaned and dry, apply a coating of rust-preventive oil to the inside of the cylinder barrels only, being very careful to see that no oil comes in contact with the surface to be metallized. **36**

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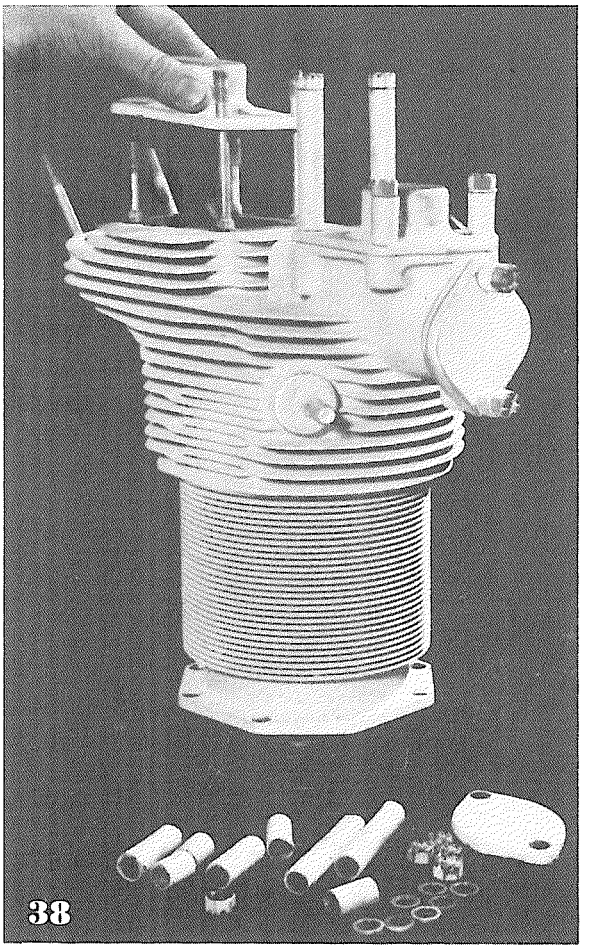
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To prepare the cylinder assembly for sandblasting, protect the cylinder assembly with Masking Equipment, AT-351. . **37** and **38** (Where pistons are to be cleaned by sandblasting, use Masking Equipment, AT-355.) This equipment prevents the sandblast from striking the machined surfaces of the cylinder head, the inside of the cylinder barrel, the valve seats and valve guides. In sandblasting, prior to metallizing, a fairly coarse grit should be used, since a slightly roughened surface makes it easier for the aluminum coating to adhere.

The quality of the metallizing finish depends to a large extent on the thoroughness with which the sandblasting is carried out. At an air pressure of 85 pounds per square inch, at least five minutes should be spent cleaning each cylinder assembly.

.....**39** and **40**

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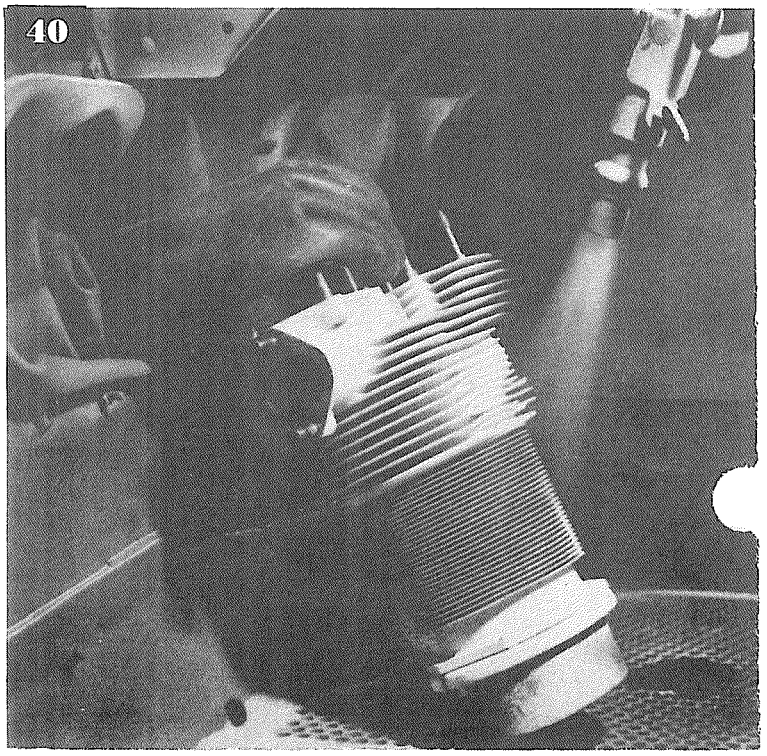
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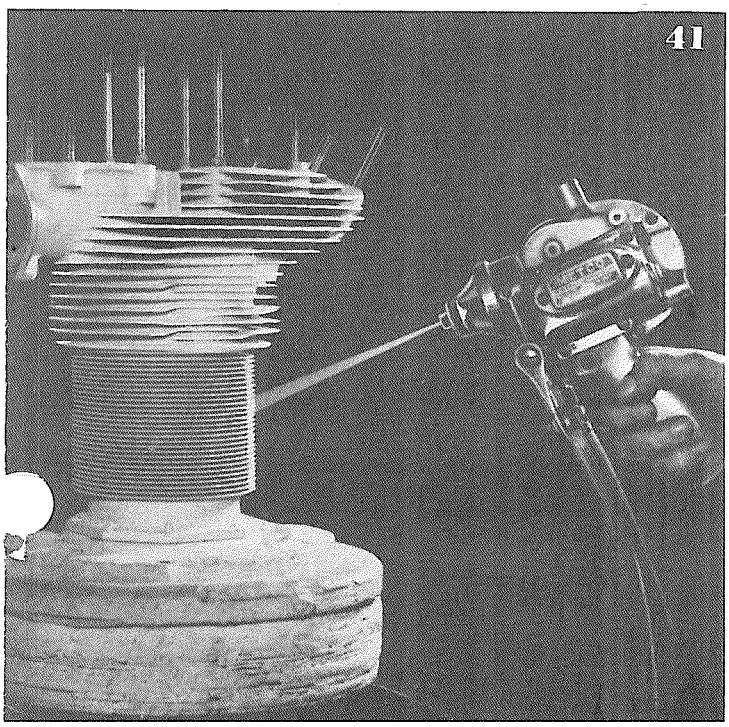
After the cylinders are sandblasted, they should, if possible, be lifted only by the masking equipment.

Moreover, they should only be handled with clean cotton gloves. A single finger print on a cylinder will cause a spot where the metallizing will not cling to the surface and may, therefore, break loose in service.

Cylinders should be metallized immediately after sandblasting to avoid deposits of moisture on the surface to be metallized.

Metallizing consists of spraying the cylinder surface with molten aluminum from a metal spray gun, which melts the aluminum wire in a flame of oxygen and acetylene and projects it onto the surface to be coated by air pressure. Air pressure for the metallizing gun should be held to 60 to 65 pounds per square inch, the pressure of the oxygen should be 17 pounds per square inch, and the pressure of the acetylene should be 16 pounds per square inch. The metallizing of a cylinder is best done by placing the cylinder on a turn-table inside the metallizing booth so that it can be rotated slowly while the metal is being applied. 41

It must be remembered that any surface at right angles to the jet of molten aluminum particles will build up the required coat of .005″ to .006″ of aluminum very rapidly. However, where the aluminum strikes the cylinder fins at an angle, the coat will be correspondingly thinner. Corrosion is most frequent between the fins of the cylinder barrel, and in metallizing particular attention should be paid to cover the entire upper and lower surface of each fin with an even coating of aluminum, by spraying the entire finned area of the barrel first with the spray nozzle held at an angle of 30° above the horizontal to cover the upper surface of each fin and then at an angle of 30° below the horizontal to cover the lower surfaces.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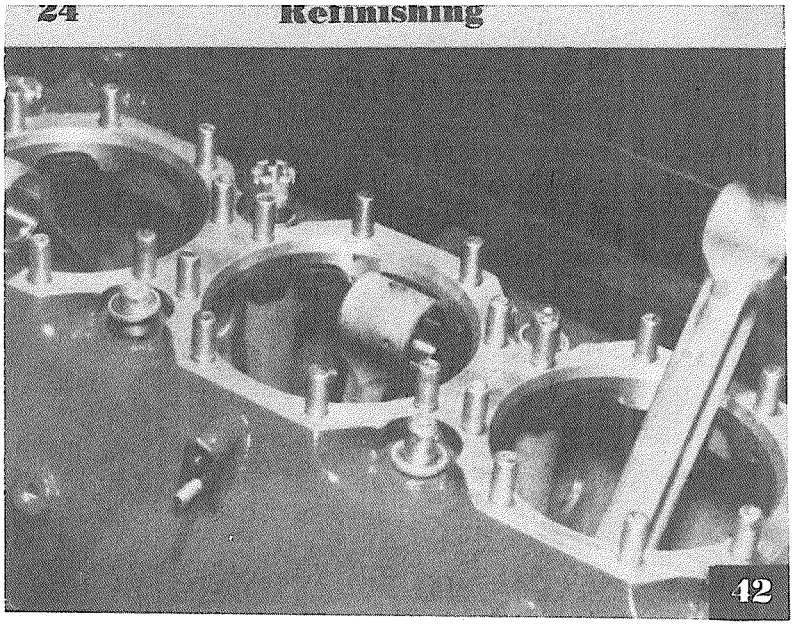
REASSEMBLY

One of the most important considerations in reassembling an engine is to guard against the possibility of foreign objects dropping inside the engine before assembly is completed. For this reason, all openings such as cylinder holes in the crankcase, intake and exhaust ports, and accessory drive openings should be kept covered. Oiled cloth bags can be used to close off cylinder holes in the crankcase.

Cloth or paper is not recommended for other locations because small pieces may tear off and fall inside the engine. Stiff cardboard, fiber board or wood is suitable for sealing most openings. It is advisable to make up several sets of covers for each particular type of engine, which can be used throughout the reassembly process.

Every part of the engine must be perfectly clean, and all moving parts thoroughly oiled before being installed. Once a part is oiled and ready for installation, it should not be touched again by cloth because of the possibility of threads clinging to the oiled surface and thus entering the engine.

When castellated nuts are installed on a stud, they must be safetied with wire. Cotter pins do not provide a positive means of locking the nut as it is still possible for the stud and nut to unscrew together. Studs can be wired to special wiring lugs, or two or three nuts may be wired together. In every case the wire, after it has been passed through the stud and nut, should be twisted in such a way that any pull on the wire will tend to tighten the nut. The wire should be tightened enough so that it cannot vibrate. However, it should not be tigh-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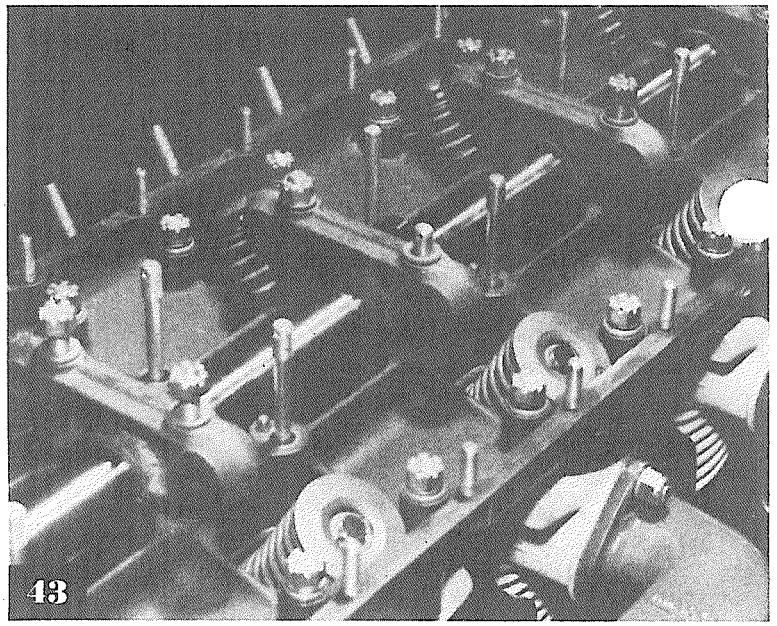

43

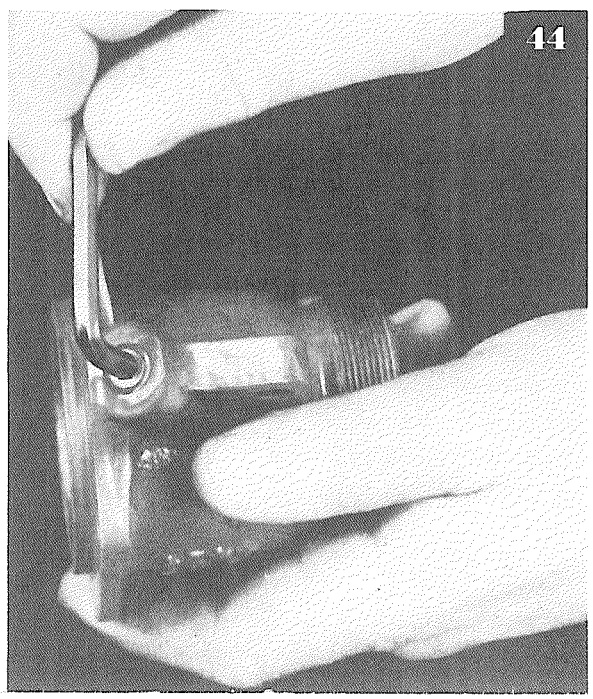
tened so much that it is stretched, as this may cause breakage in service.

The special washers under the main bearing stud nuts and under the nuts holding the camshaft housings to the cylinders, are designed to evenly distribute the pressure of the nut over a large area... **42** and **43** They should, therefore, not be replaced with smaller or thinner washers.

When nuts are placed on steel shafts, they should be screwed on by hand very slowly and if the slightest binding is felt, they should be backed off immediately. Forcing a nut over a bad thread will cause the nut to seize and may cause rejection of the part. If a thread appears rough, the nut should be lapped on the shaft with fine lapping compound. In most cases, a light lapping with a mixture of talcum powder and oil will be sufficient.

Thread lubricant should be used on all pipe plugs. Allen plugs should be installed using the correct size Allen wrench... **44**

Square headed pipe plugs should be installed with a 4 point or 8 point socket wrench. Trying to remove square plugs with a 12 point wrench will invariably cause damage to the plug which will make it extremely difficult to remove it. All intake gaskets and gaskets which seal passages carrying oii under pressure should be covered with sealing compound before installation. In certain other locations which are named in the appropriate section of this book, a silk thread is used as an oil seal. Whenever this method is used, the parting surface should first be covered with gasket compound and the silk thread should then carefully be placed on the parting surface so that it passes on the inside of all stud holes, but around the outside of any oil transfer dowel holes. **45**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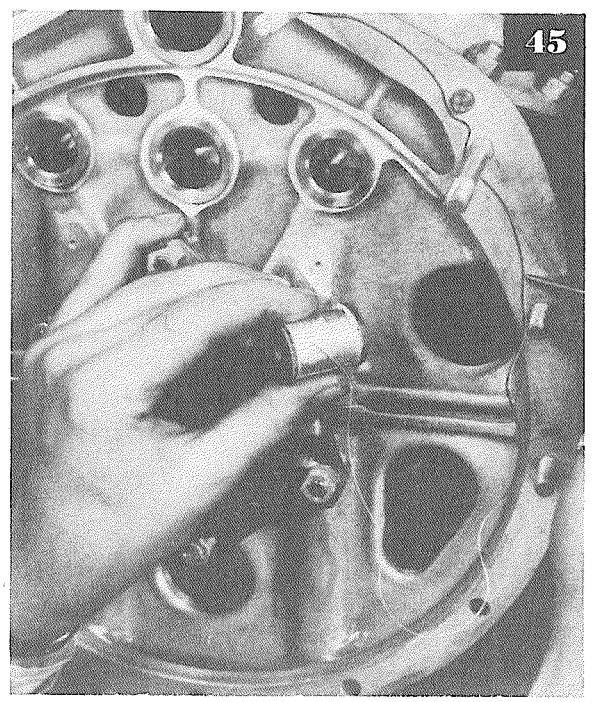
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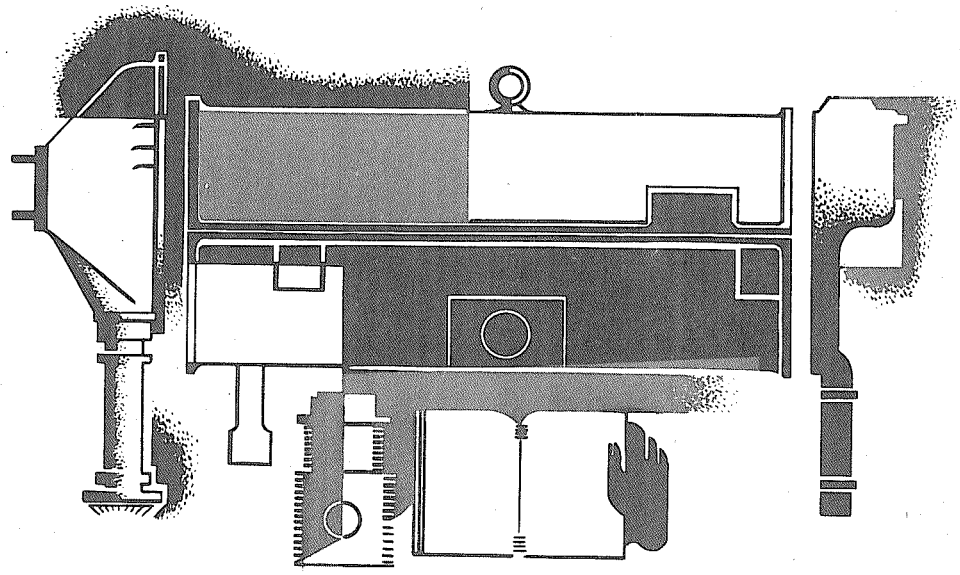
CHAPTER II



DISMANTLING AND DISASSEMBLY

The following chapter covers the complete dismantling and disassembly of the engine into its component parts.

When the engine is delivered in a box, first examine the box for any evidence of damage sustained in shipping. Move the engine box directly below a chain hoist. Cut the safety wire through the cap screws holding the two halves of the engine box together. 53

Remove the two cap screws from each of the four binding strips which hold the cover and the lower half of the box together. Lift the cover straight up until it completely clears the engine before starting to move it sideways. This will eliminate the possibility of the cover striking any part of the engine. The cover can be lifted either by hand or by using a hoist.

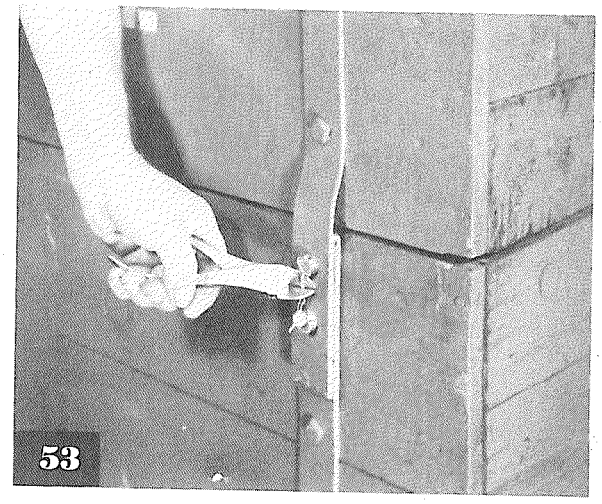
The engine is supported in the box on mounting brackets bolted to mounting rails which extend the length of the box on each side of the engine. Remove the nuts and washers that secure the mounting rails to the box.

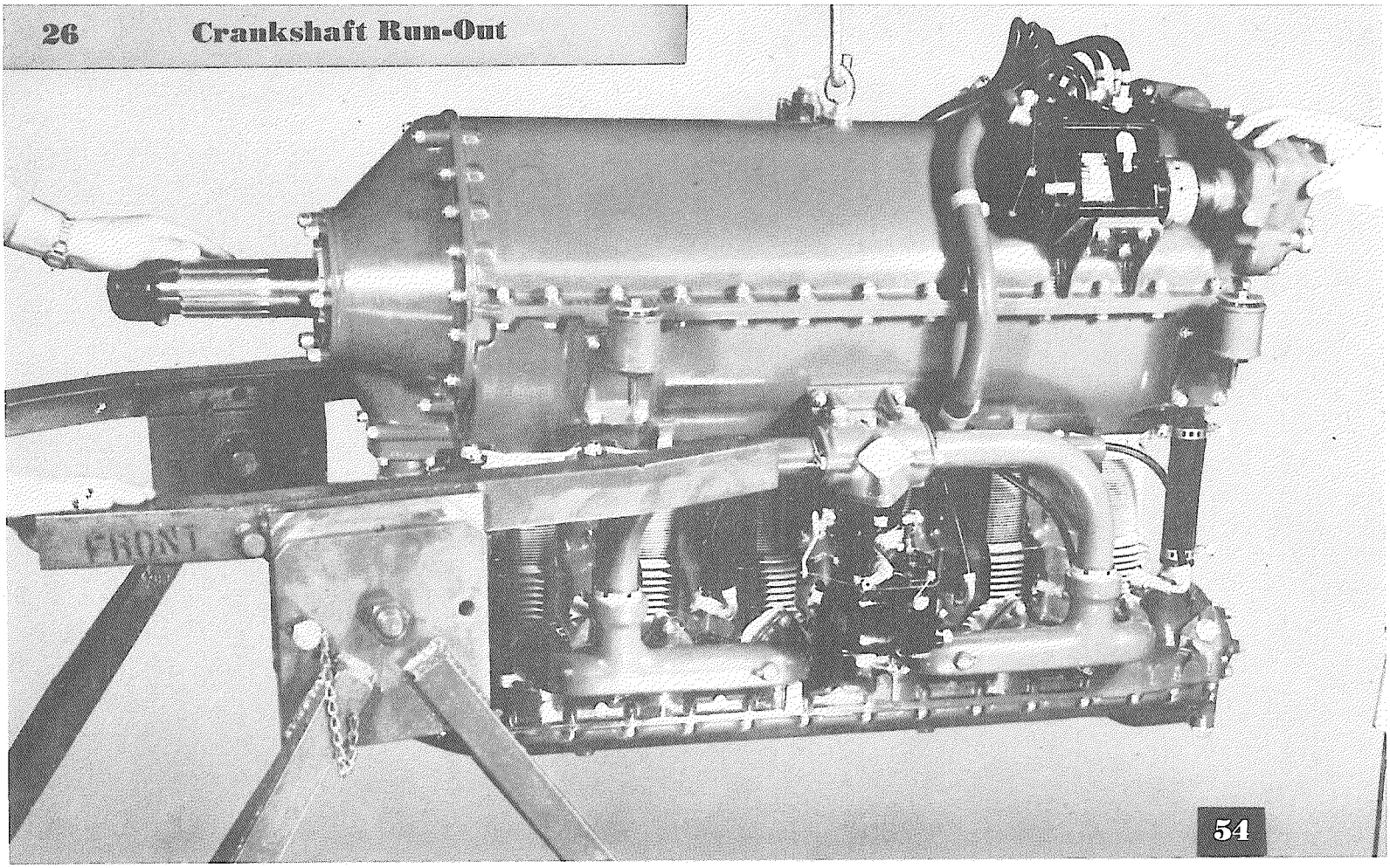
Using the hoist, lift the engine from the box until it is clear of the box.

Remove the mounting rails by taking out the four bolts which secure them to the four shipping brackets.

Care must be taken during this operation not to damage the engine through contact with the shipping box.

Remove the box from below the engine. At this point carefully examine the entire engine and record condition of all parts, list all missing parts and the serial numbers of all the accessories on the Engine Receiving Inspection Report shown in Chapter VIII.





The engine should then be placed on an Engine Assembly Stand, AT-182. When mounting the engine on the stand, see that the cradle of the engine stand is securely locked in position and that the front of the engine is toward the front of the stand, so as to be in balance while being inverted.**54** Also, make sure that the four mounting bolts are securely tightened.

With the engine on the movable engine stand, it can be moved to the location where it is to be disassembled.

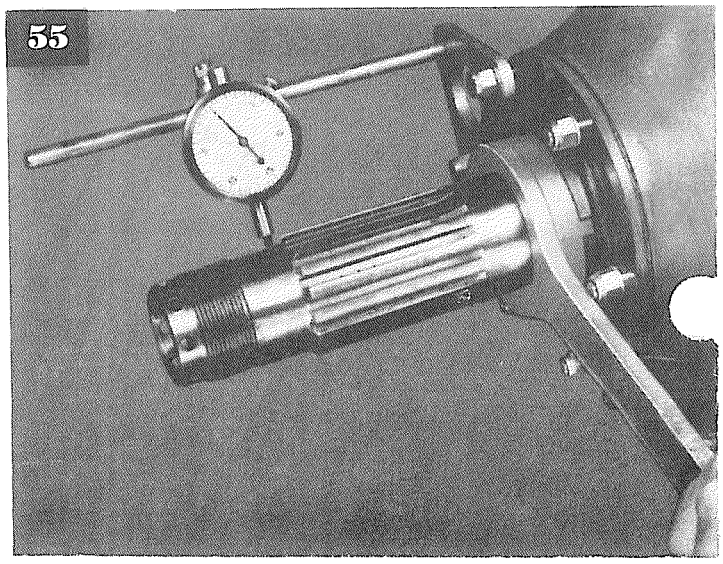
Crankshaft Run-Out and End Play Check

Before starting to dismantle the engine, the crankshaft should be checked for run-out and end play with a dial indicator as follows:

Remove the exhaust side spark plugs using Spark Plug Wrench, AT-153, for unshielded plugs, or Spark Plug Wrench. AT-39, for shielded plugs.

Remove the nuts from two adjacent front crankcase cover studs, install Run-Out Indicator Support, AT-185, and replace the nuts. Slide Thrust Nut Wrench, AT-137, over the crankshaft and engage with the thrust nut. Clamp a dial indicator to the support in such a position that the end of the spring plunger bears against the front propeller cone nut. **55**

Check run-out of crank-shaft on front cone seat by turning the shaft with the thrust nut wrench. Refer to Table of Limits, Chapter IX of this manual, for maximum allowable deflections of the crankshaft. After this, dummy plugs should be installed in the spark plug holes.



The crankshaft end-play due to thrust bearing tolerance, should be checked with a dial indicator as follows:

Remove the thrust nut wrench and adjust the dial indicator so that the end of the spring plunger bears against the forward face of the thrust nut. Work the crankshaft back and forth as far as it will go and note the full movement on the dial indicator. Refer to Table of Limits, Chapter IX of this manual, for maximum allowable end play.

Remove dial indicator and indicator support and then loosen the thrust nut about one-half turn. This is important because it is extremely difficult to loosen the thrust nut after the nose section has been removed. **56**

Removal of Accessories

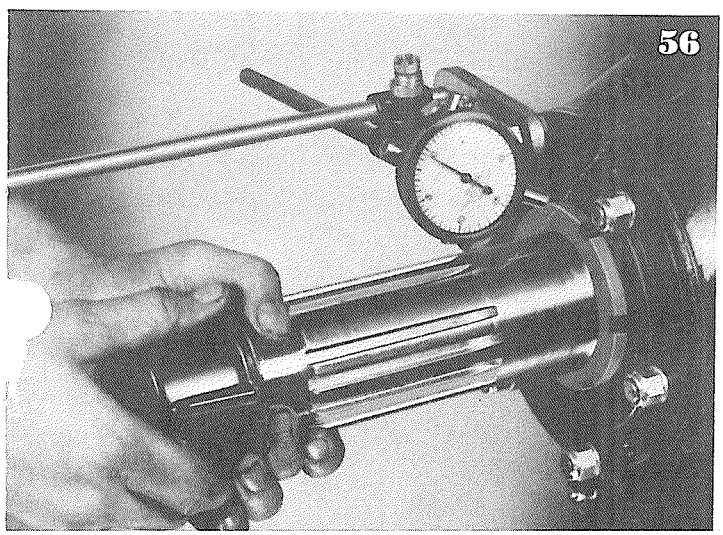
To facilitate the dismantling of the engine, it is advisable to first remove all the accessories that are mounted on the engine. As soon as an accessory is removed, all exposed openings must be covered.

Remove the four self-locking nuts holding the generator, or the generator replacement cover, to the crankcase and remove the generator. **57**

Remove the six self-locking nuts holding the starter, or the starter replacement cover, to the crankcase rear and remove the starter. **58**

Remove the four self-locking nuts attaching the fuel pump, or the replacement cover, to the scavenge oil pump and remove the fuel pump. **59**

Remove the four self-locking nuts holding the vacuum pump, or the replacement cover, to the tachometer drive housing, and remove the vacuum pump. **60**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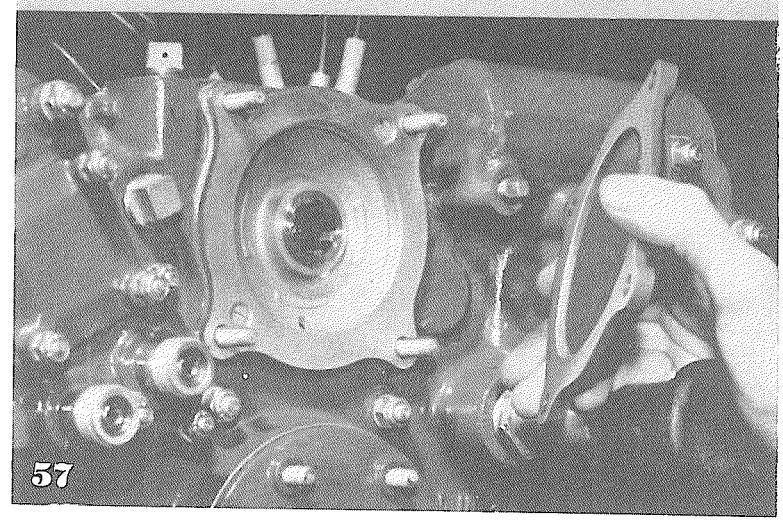
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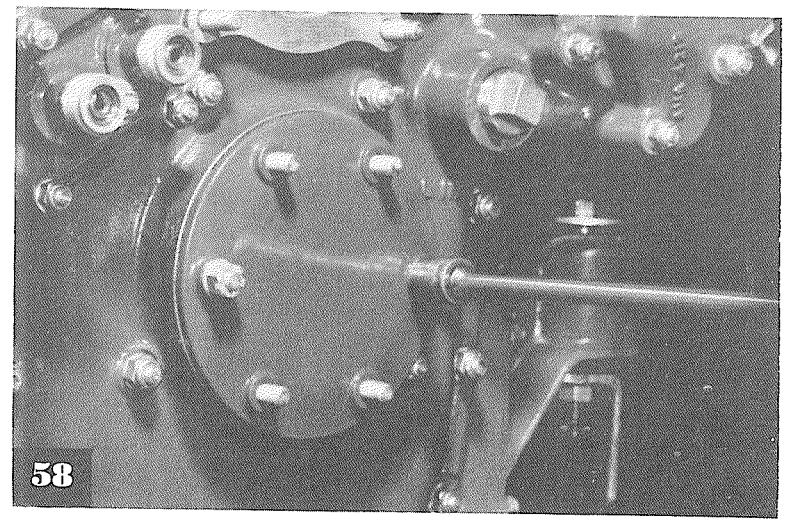
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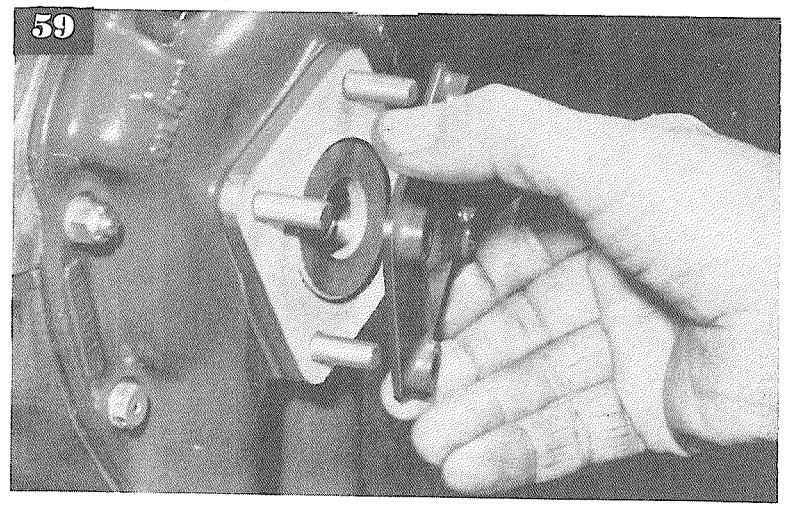
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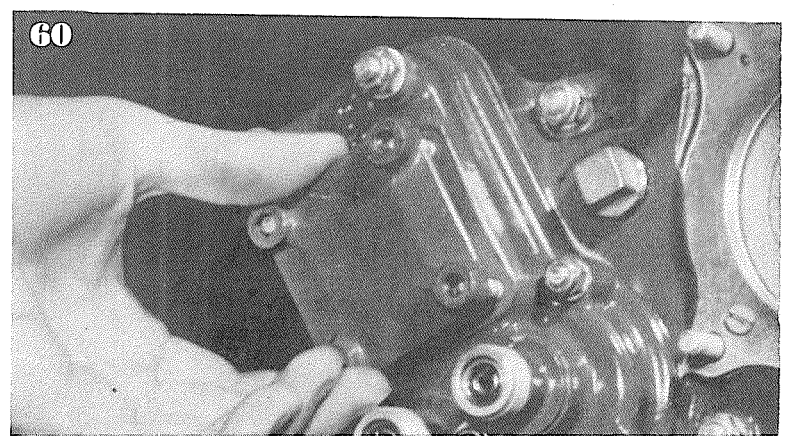
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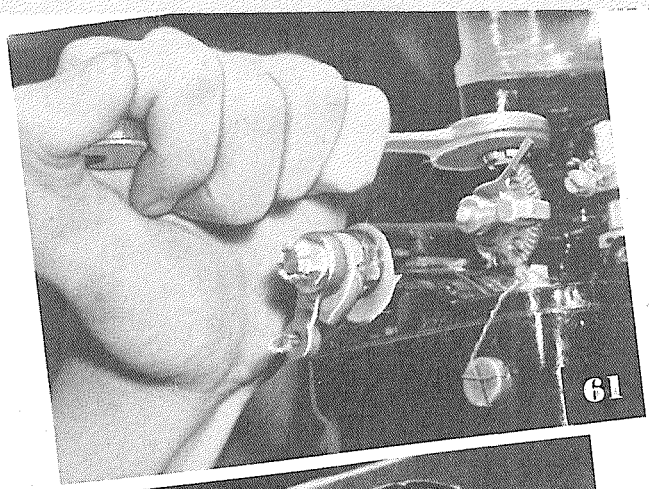
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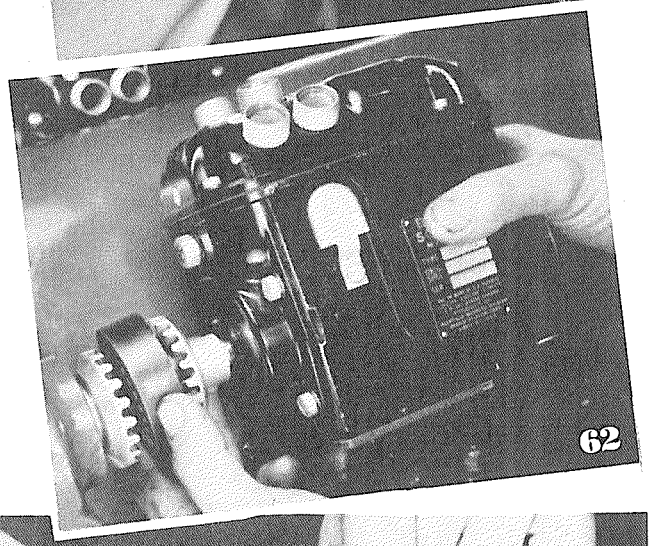
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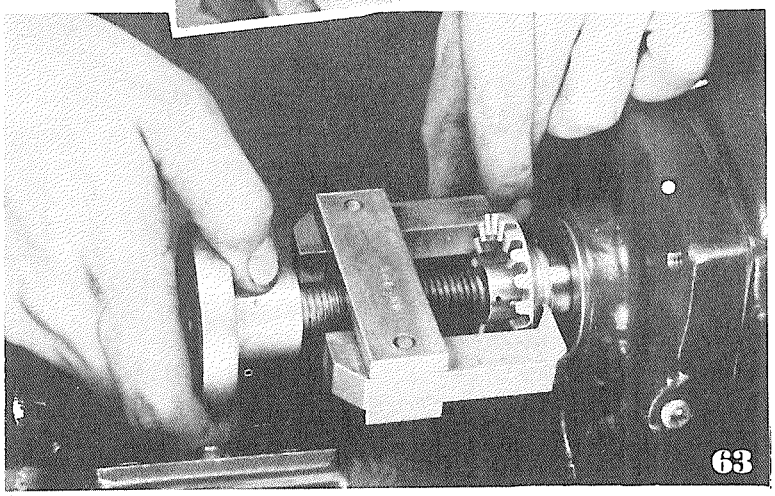
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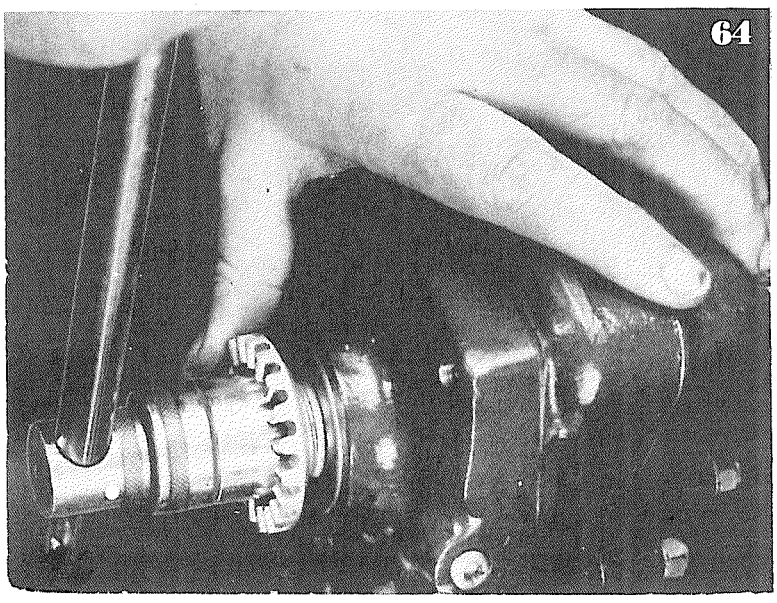
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Take out the cotter pins. Remove the castle nuts securing the carburetor to the hotspot, and remove the carburetor. .....**61** The Marvel-Schebler carburetor is fastened to the hotspot by four studs and nuts while only two are used to attach the Stromberg carburetor.

Disconnect the spark plug wires from the magnetos by unscrewing the knurled coupling nuts. Remove the four capscrews holding each magneto to the base mounting pads on the upper crankcase, and remove the magnetos, being careful to lift them high enough to clear the dowel pins. .....**62** Remove magneto intermediate rubber couplings.

Wire Harness

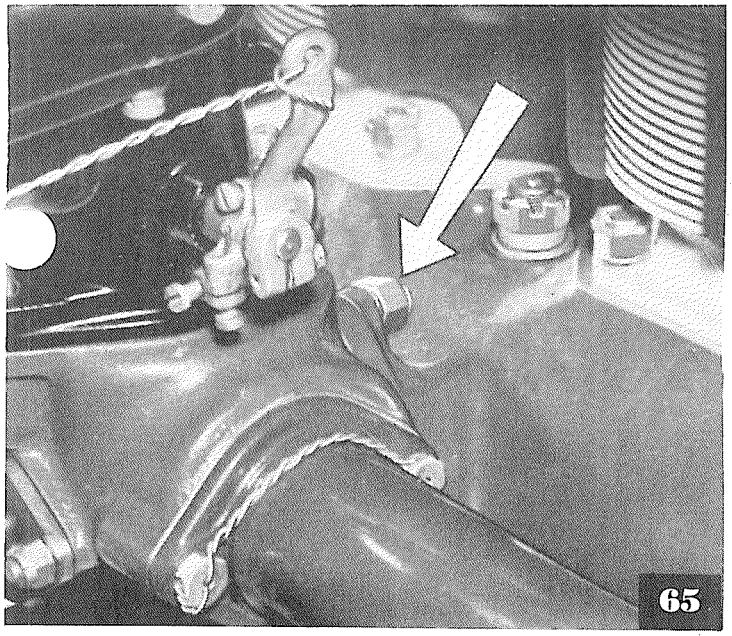
Disconnect all wires from the intake spark plugs. Remove the screws from ignition wiring manifold clips, and remove the manifold assembly complete. Remove the magneto terminals, ferrules and nuts from the ignition wire. Remove wires from manifolds. Remove the spark plug terminals. On unshielded ignition wiring assemblies, the wires must be unsoldered to remove the spark plug terminals.

Magneto Drive Couplings

Remove the nuts holding the magneto drive couplings to the magneto drive gears. Remove the drive coupling, using a Magneto Drive Coupling Puller, AT-147. .....**63** Remove the magneto driven coupling retaining nut from the right magneto while holding the driven coupling with a Magneto Coupling Wrench, AT-148. .....**64** Remove the driven coupling. Remove the magneto coupling shims, if any. Tag the shims, carefully noting their proper location. Remove the woodruff key, taking care not to damage the shaft.

Intake Assembly

Loosen the intake pipe packing nuts between the intake pipes and manifolds, using an Intake Pipe Packing Nut Spanner Wrench, AT-46. Remove the 12 self-locking nuts attaching the intake manifolds to the cylinders. Remove the three self-locking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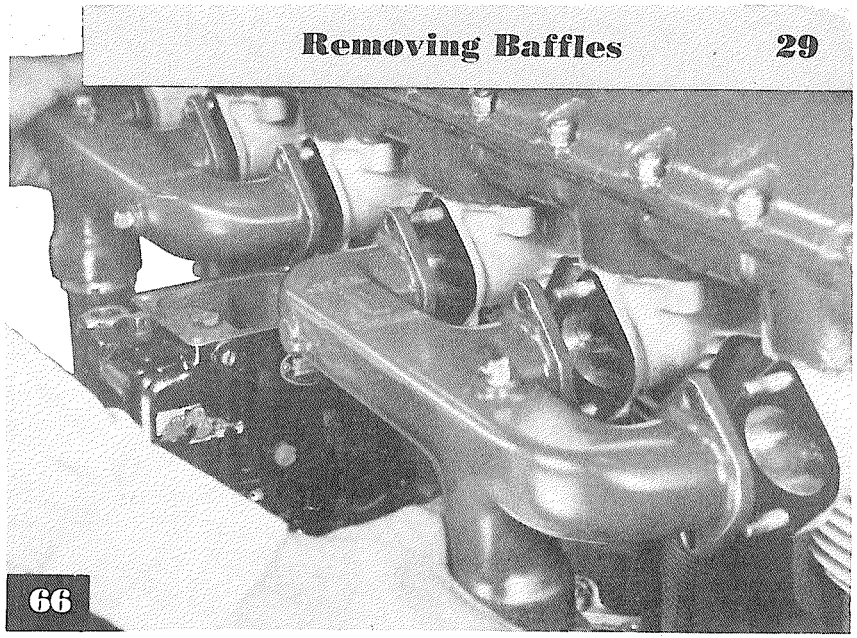
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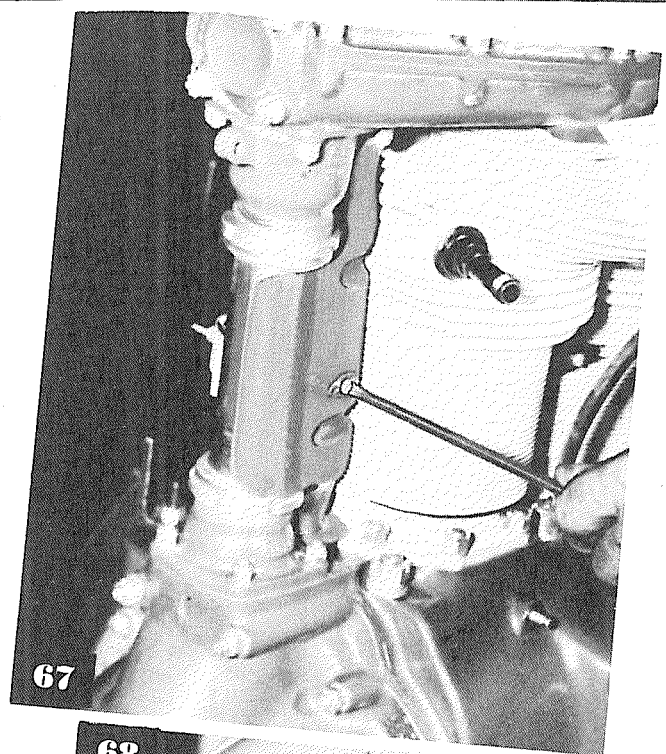
nuts attaching the hotspot to the crankcase. One of the nuts holding the hotspot in place is located behind the hotspot mounting flange on the crankcase. **65**
The intake pipe and manifold assembly should now be removed as a complete unit and placed on the work bench. **66**
Remove the four cap screws attaching the intake pipes to the hotspot and separate. Unscrew the intake pipe packing nuts and separate the intake pipes and manifolds. The intake side spark plugs can now be removed, and in their place dummy plugs installed.

Baffles

To remove the front cylinder baffle it is necessary to first remove the screw between the baffle and the spring assembly. . . . **67**
This will release the clamping action of the spring to the vertical drive shaft housing and permit the baffle to be removed. . . **68**
The intermediate cylinder baffles are removed by removing the screws attaching the baffles to the baffle clamps. **69**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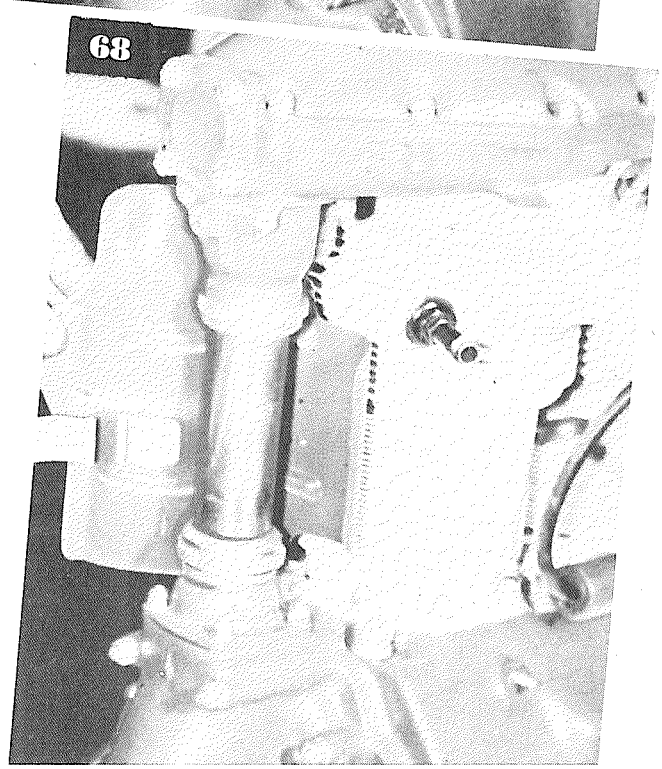
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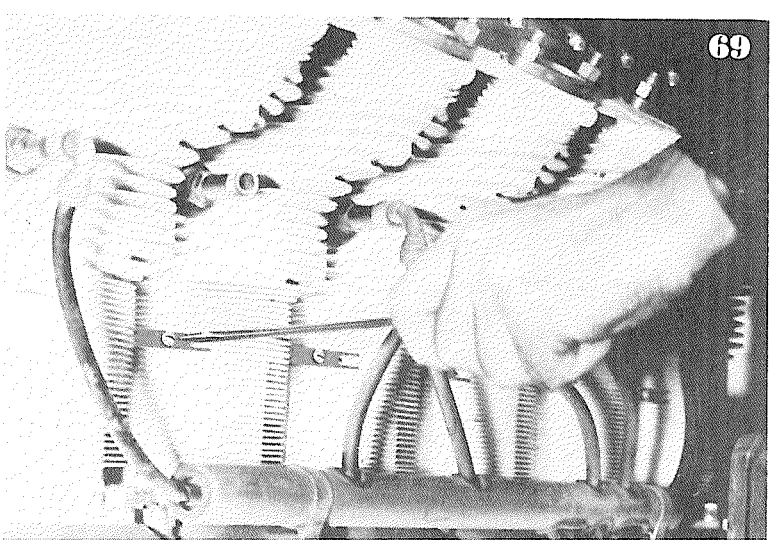
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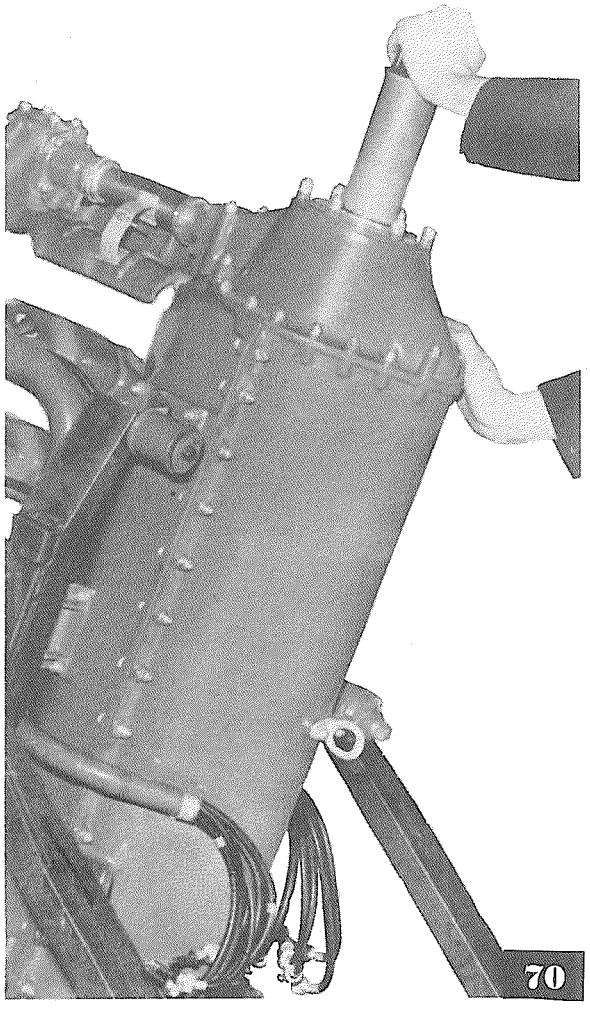
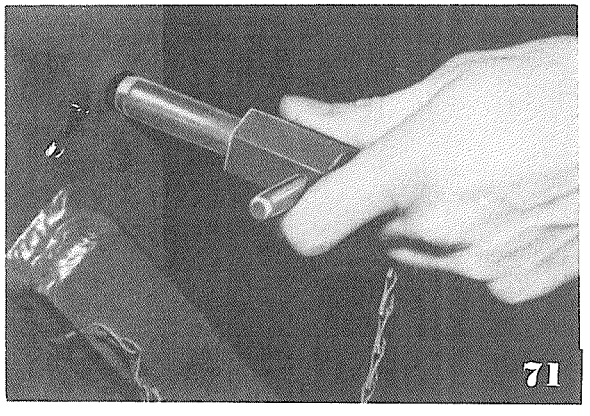
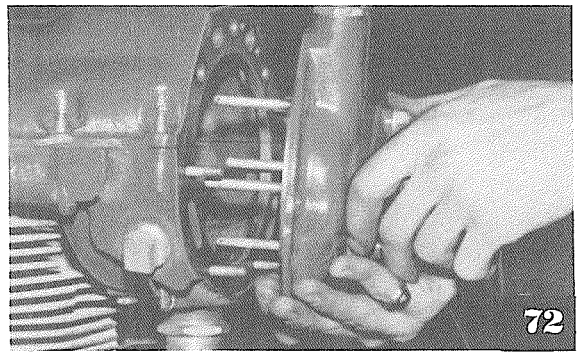


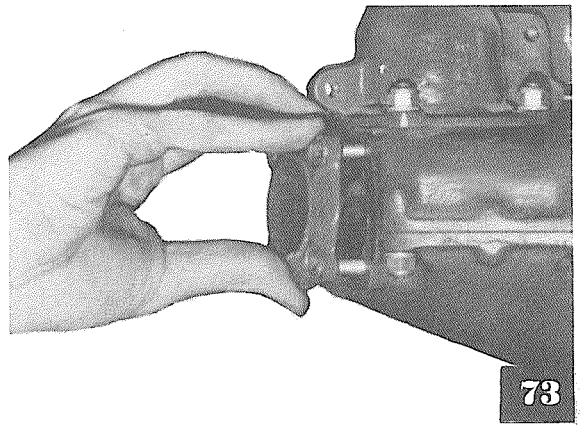


Scavenge Oil Pump Drain Plugs

Cut the lockwire and remove the two strainer plugs from the bottom of the scavenge oil pump. Tilt the engine at a 45° angle and allow any trapped oil to drain out.

Make a close examination of the strainers and magnets to see if any foreign matter has entered the lubrication system. Replace strainer plugs to keep foreign matter out of pump.





Invert Engine

Remove pins locking the cradle in engine stand and invert the engine. Be sure to swing the propeller end up and over so as to clear the base of the stand. **70**
Lock the cradle with both pins. **71**

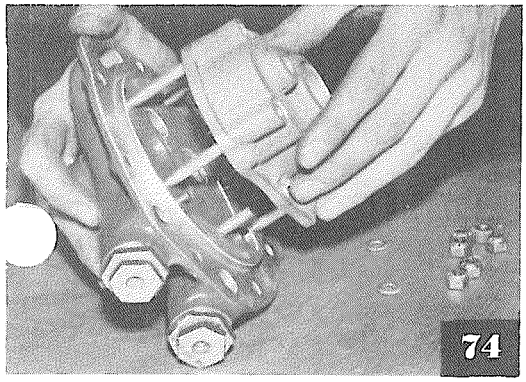
Camshaft Housing Cover and Scavenge Oil Pump

Remove the four nuts attaching the camshaft housing front end cover, and remove front end cover. Tap loose with a composition mallet or fiber drift if necessary. . . **72**

Loosen the two rear nuts on each side of the camshaft housing cover and remove the four nuts and three capscrews attaching the scavenge oil pump. Remove the pump. . **73**
Tapping it back lightly with a composition mallet if necessary. Be careful not to drop the scavenge pump drive shaft when withdrawing the pump. Remove the scavenge pump drive shaft.

Remove all the camshaft housing cover attaching nuts and remove the cover. It is not necessary to remove the scavenge oil pipe in the camshaft housing cover unless signs of damage are apparent.

Cut the lockwire and remove the six castellated nuts attaching the scavenge oil pump cover to the pump housing. Hold the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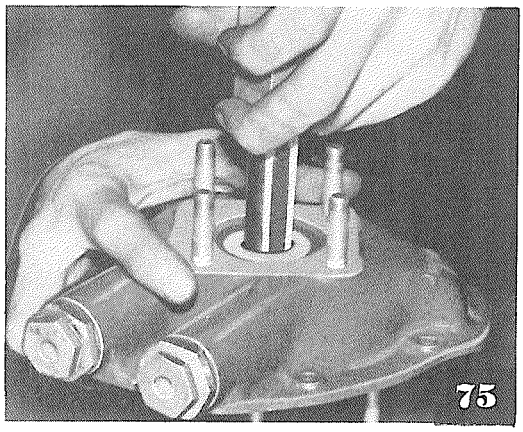
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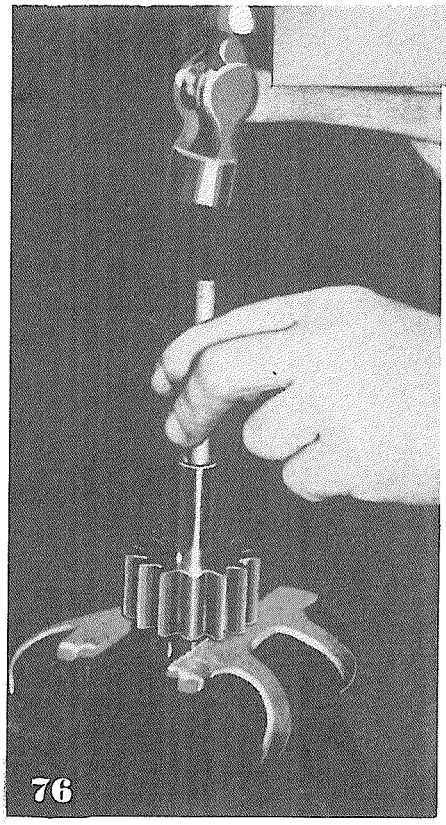
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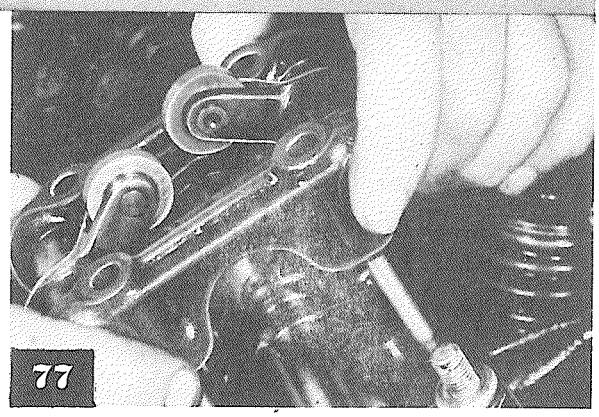
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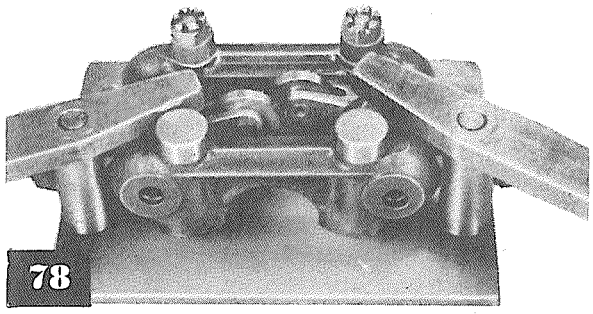
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housing and tap lightly near parting surface with composition mallet to separate cover and housing. **74**

Remove all the gears, shafts, magnetic plugs and strainers from the housing and cover. Remove the oil retainer using a Fuel Pump Drive Oil Retainer Remover, AT-228. . . . . **75**

Place the scavenge oil pump drive gear in a vise equipped with copper jaws, and drive out plug in forward end. **76**

Rocker Arm and Support Assemblies

Remove all the lockpins, nuts and washers holding the rocker arm supports. Loosen the supports by turning the camshaft and remove rocker arm and support assemblies as complete units. **77**

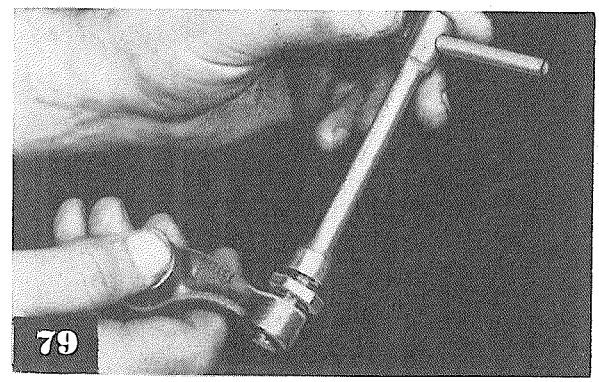
Separate the two rocker arm supports using Rocker Arm Support and Camshaft Bearing Assembly Separator, AT-209. . . **78**

Withdraw shafts from rocker arms. Loosen the check nut of the valve rocker adjusting screw and remove both the nut and screw together. **79**

Do not attempt to remove the flattened ball from the adjusting screw.

Early engines have needle bearings installed in the rocker arms while later engines have bronze bushings. Needle bearings must be replaced at each overhaul while bushings need be removed only if they are defective. The procedure for removal is identical for both. To remove the bearing or bushing, insert Rod, AT-145-3, into the rocker arm from the long side of the hub.

Insert the drift into the Press Assembly, AT-145-1, and press out both bushings or bearings in an Arbor Press. **80**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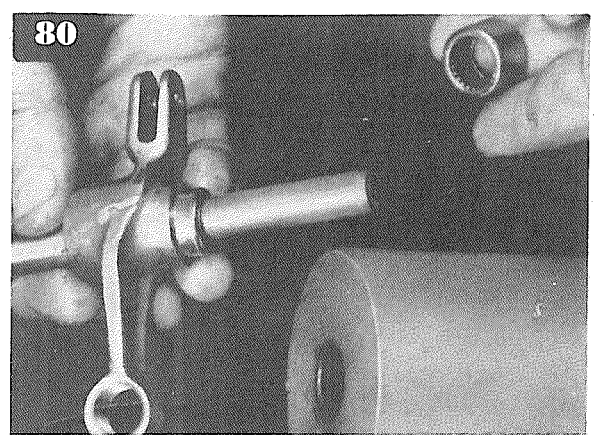
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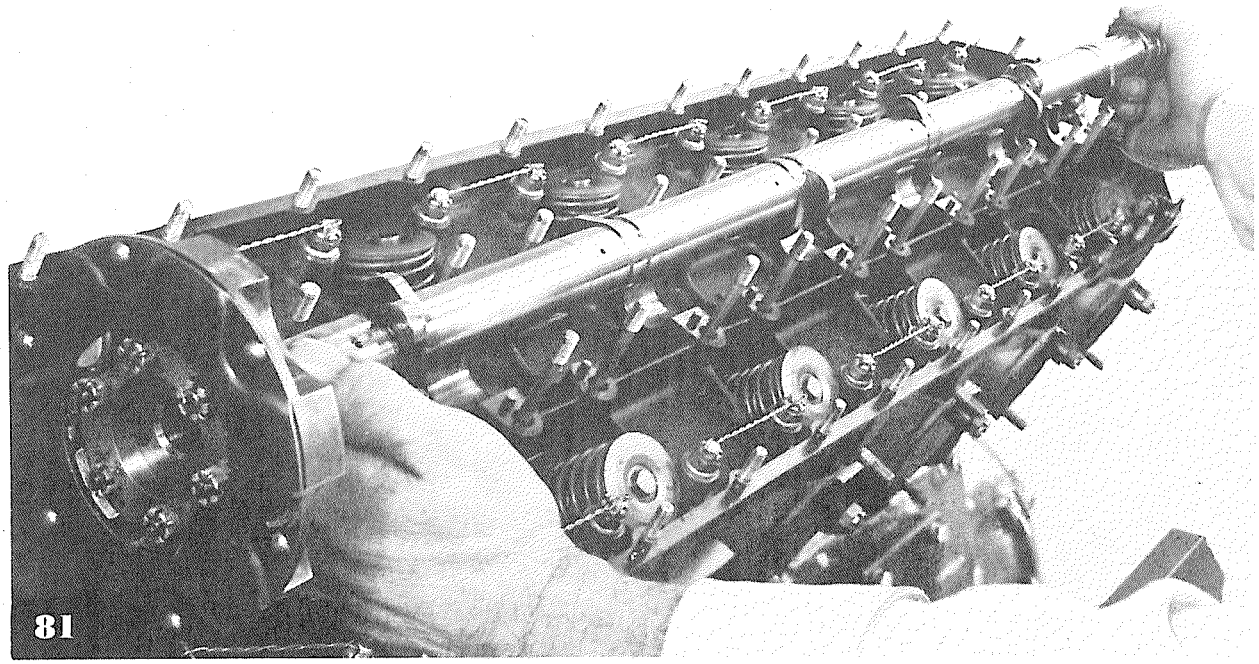
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Removal of Camshaft

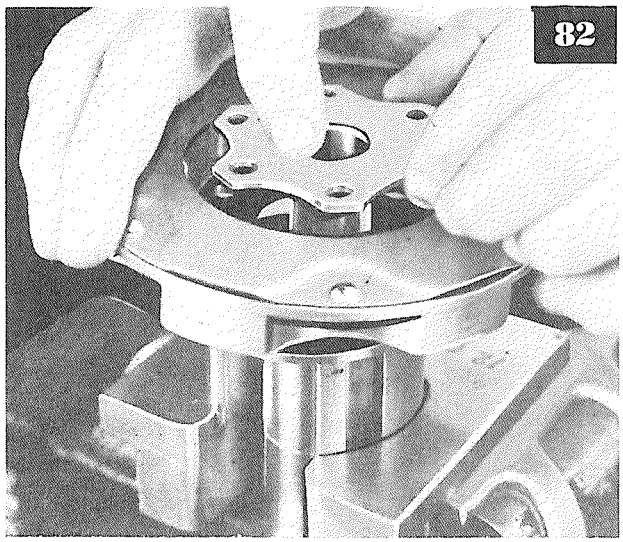
Remove the two nuts holding the front camshaft bearing cap to the camshaft housing, and remove the bearing cap.

Lift out the camshaft assembly as a complete unit. Care must be taken not to damage the journals or cam lobes during this operation. **81**

To dismantle the camshaft assembly, place it in a vise in a suitable holding fixture. Where a special fixture is not available, the shaft may be clamped between copper jaws, making sure to clamp the shaft between the journals. Clamp the shaft in a vertical position with the flywheel about six inches above the top of the vise. Remove the cotter pins and take out the six bolts which hold the damper assembly to the rear of the camshaft. Remove the scavenge oil pump adapter. **82**

Do not remove the cup plug in the adapter. Take off the camshaft damper assembly. Earlier type camshaft flywheels having six damper weights, are constructed with inner and outer damper weight retainers. Removal of the inner retainer permits two of the damper weights to be taken out. These two weights should be removed at this time. **83** Do not remove the rivets attaching the camshaft damper retainer to the camshaft flywheel.

Turn the camshaft around so that the forward end faces up and again secure in the vise. Remove the front end nut, the washer, the camshaft gear, the special camshaft gear thrust washer, and the camshaft bushing. The thrust washer should be immediately tagged as to its location, as it is especially ground to fit only in this particular location.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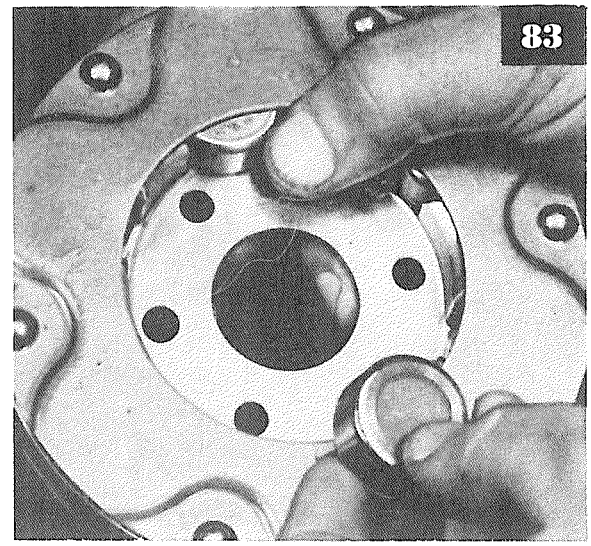
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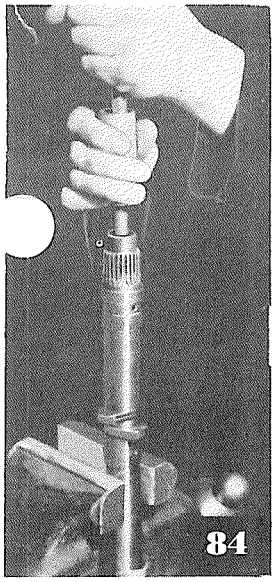
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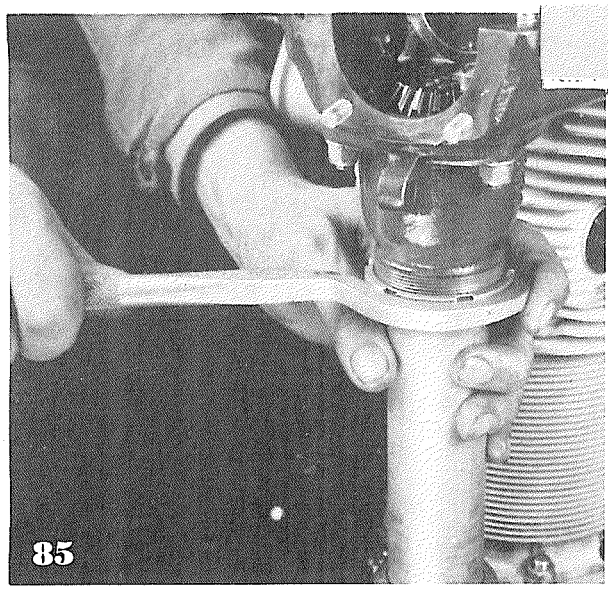
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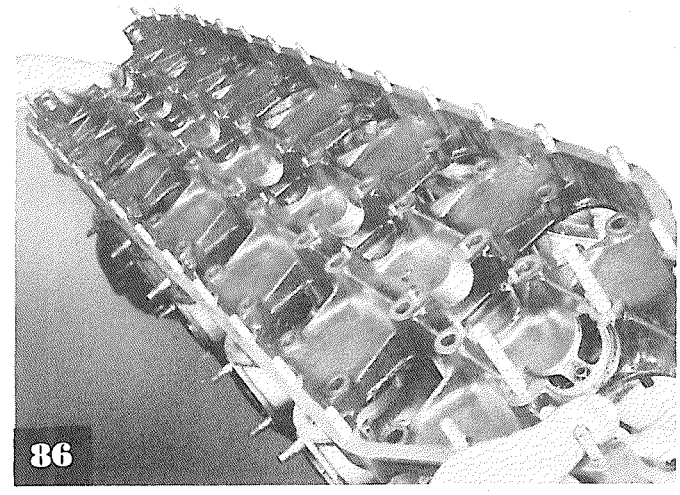
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Drill a hole in the cup plug in the front end of the camshaft and remove the plug, using Cup Plug Puller, AT-379. .....**84**
If the shaft has plugs in the front and the rear ends, both plugs should be removed.

Camshaft Housing

Loosen the upper and lower vertical drive packing nuts using Wrench, AT-46. .....**85**
Remove the four nuts holding the lower vertical drive housing support to the camshaft housing. Loosen the clamps on the rear oil drain hose and remove the hose. Remove the twenty-four nuts attaching the housing to the cylinders and lift off the camshaft housing. **86**
Remove the screws holding the cylinder head baffles to the camshaft housing and lift off the cylinder head baffles.

Vertical Drive Shaft Assembly

Remove the cotter pin and loosen the nut attaching the vertical drive shaft lower gear. **87**
This should be done first as it is extremely difficult to loosen the nut after the assembly is removed from the engine.

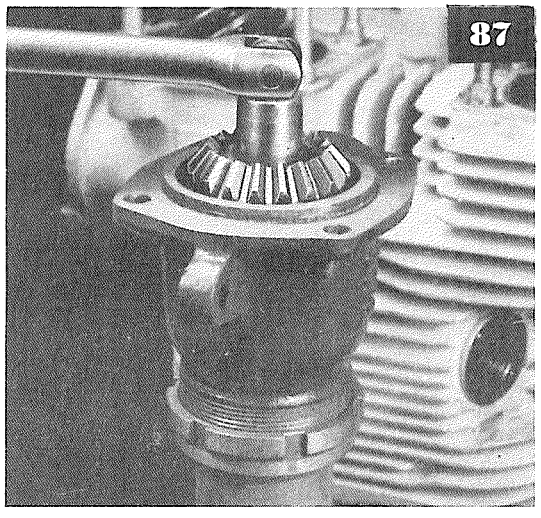
Remove the four nuts holding the upper vertical drive housing support to the front crankcase and lift out the vertical drive assembly as a unit. **88**
Remove the nut, washer and the lower vertical drive gear and thrust washer. Remove the vertical drive shaft and the vertical drive shaft upper gear and thrust washer. Make sure that the thrust washers are immediately tagged showing their exact locations.

Drill a hole in the cup plug in the upper end of the vertical drive shaft and remove the plug with Cup Plug Puller, AT-379. **89**

Unscrew the vertical drive shaft housing packing nuts and separate the upper and lower housing supports from the vertical drive housing. Remove the packing nuts and the packings from the housing.

Cylinders and Pistons

Place the Timing Indicator, AT-166, or Spline Wrench, AT-602, on the crankshaft and rotate shaft with the turning handle un-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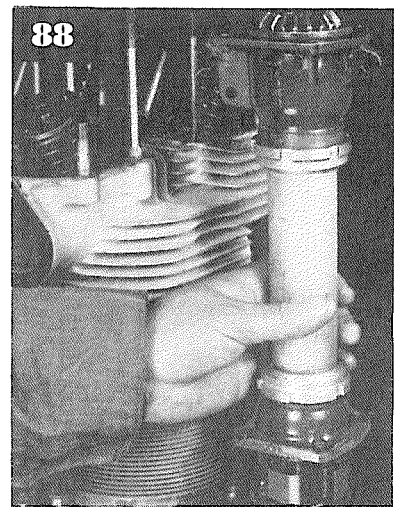
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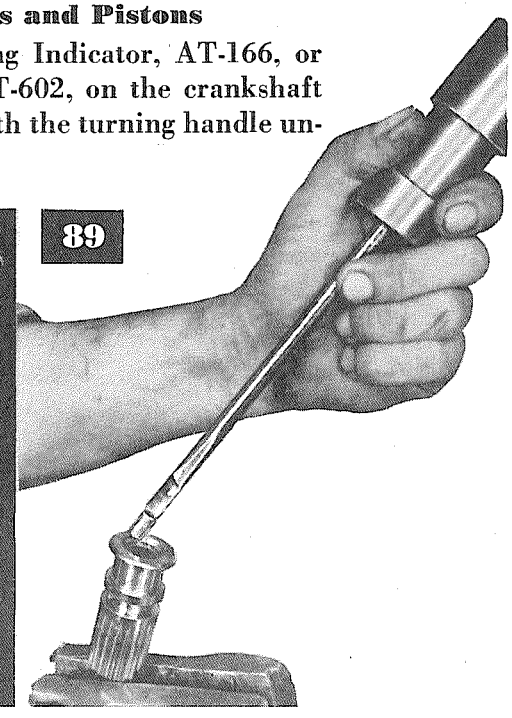
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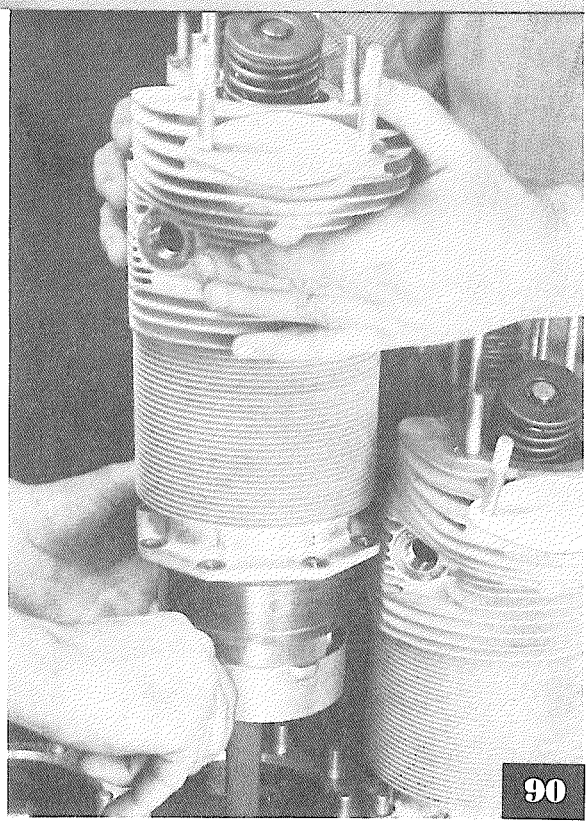
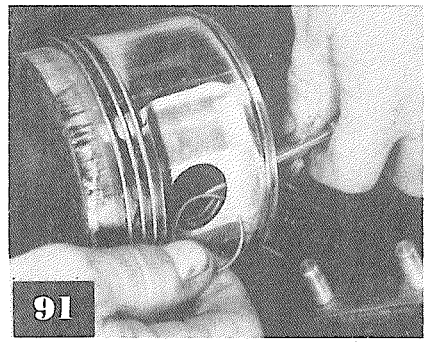
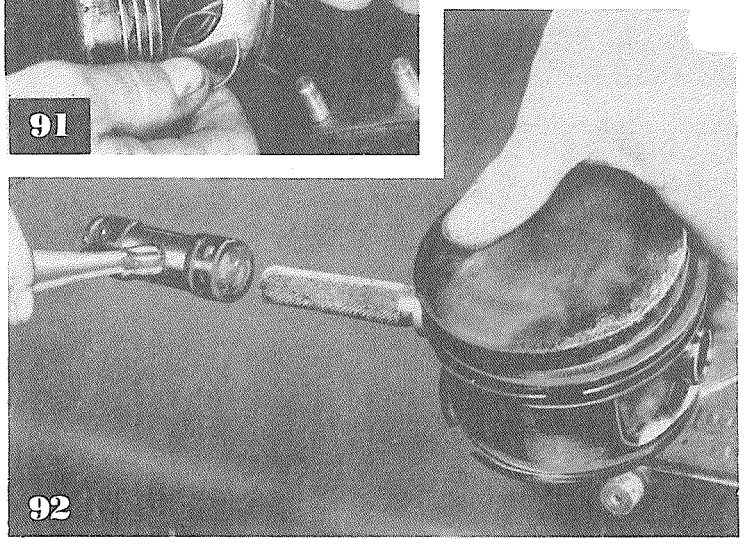


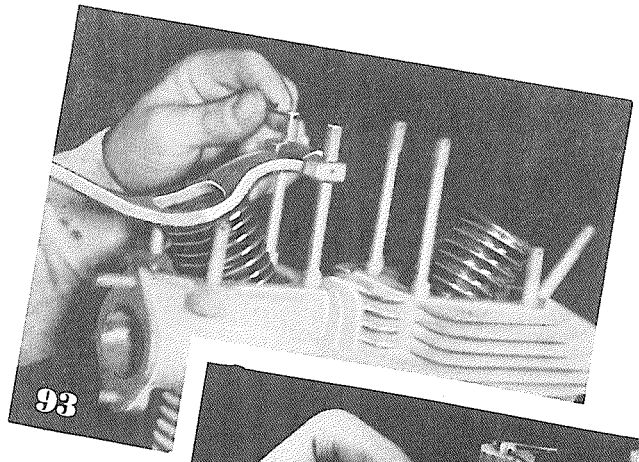
til No. 1 and No. 6 pistons are at the top dead center position. At this point the master spline on the crankshaft points directly toward the cylinders. Remove the eight cylinder retaining locknuts and eight cylinder retaining nuts from No. 1 cylinder hold down flange and lift off No. 1 cylinder. . **90** Care must be taken to prevent the pistons and the connecting rods from striking the crankcase to prevent possible damage.

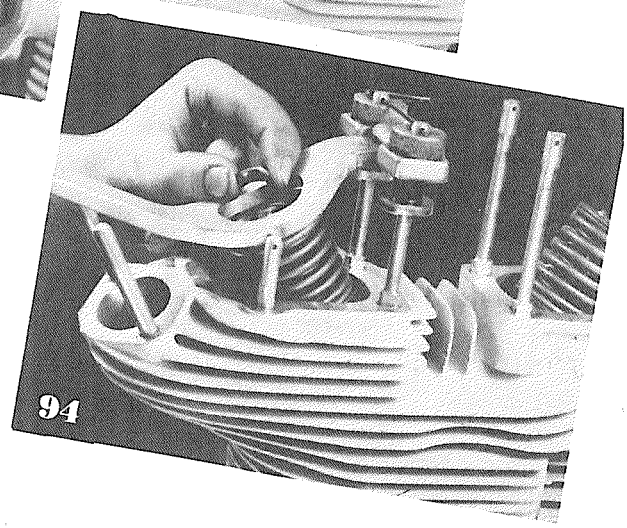
Insert the Piston Pin Circlip Remover, AT-186, in the hole drilled from the bottom of the piston into the piston pin boss, and remove the front circlips. . . . . **91** Slide out the piston pin. If the pin is tight, use Piston Pin Drift, AT-142. . . . . **92** Brace the rod so as not to force it out of alignment. Remove the No. 6 cylinder, rear circlip, piston pin and piston in the same way and observing the same precautions.

Rotate the crankshaft 120 degrees in a clockwise direction (counter clockwise as viewed from the front of the engine) and remove No. 2 and No. 5 cylinders and piston assemblies. Rotate the crankshaft another 120 degrees in the same direction and remove No. 3 and No. 4 cylinders and piston assemblies.



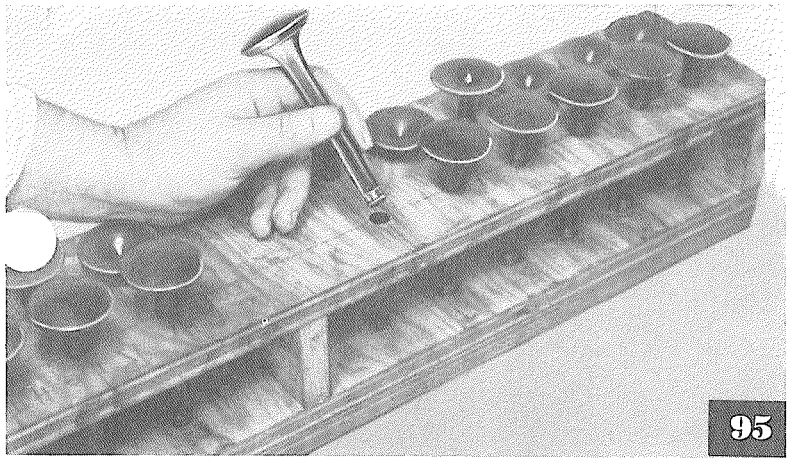






Place cylinder on the Cylinder Assembly Block, AT-215. Remove the nuts from the exhaust port studs and lift off the exhaust port covers and adapters.

Place Valve Spring Compressor, AT-14, on the long necked cylinder head studs . **93** Compress the valve springs on one side, lift out the split valve locks. **94**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and release the springs slowly. Remove the valve spring compressor and take off the outer spring washer and both valve springs. Repeat this operation to remove the other set of valve springs. Inspect the valve stems for scores, nicks or scratches. If any are found, they should be stoned out before valves are removed from valve guides.

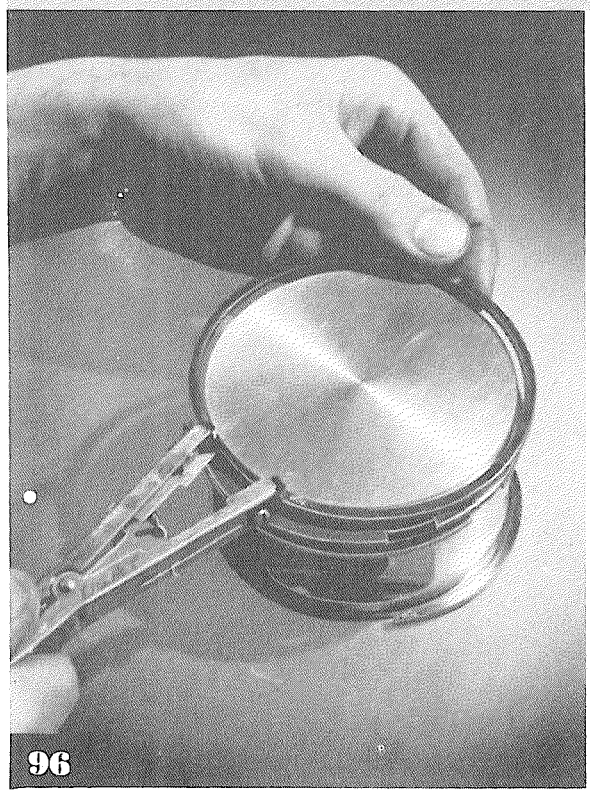
Hold the valve stems with the thumbs to keep valves in closed position, lift the cylinder from the assembly block and place it on the bench in a horizontal position. Remove the valves and place them in a Valve Rack, AT-373. . . . . **95**

Do not remove valve guides, valve seats or spark plug inserts. If subsequent inspection shows reworking or replacement of any of these parts to be necessary, refer to Chapter IV for detailed instructions.

Using Piston Ring Expander, AT-122, remove the piston rings from all pistons. . **96** Remove the remaining circlip from each piston. Piston pins should always be kept with their respective cylinders or should be tagged for location.

Removing the Front Crankcase

Remove the thrust nut from the crankshaft. Remove the six nuts and six spacers from the front crankcase studs and remove the front crankcase cover using Puller, AT-140. . . . . **97**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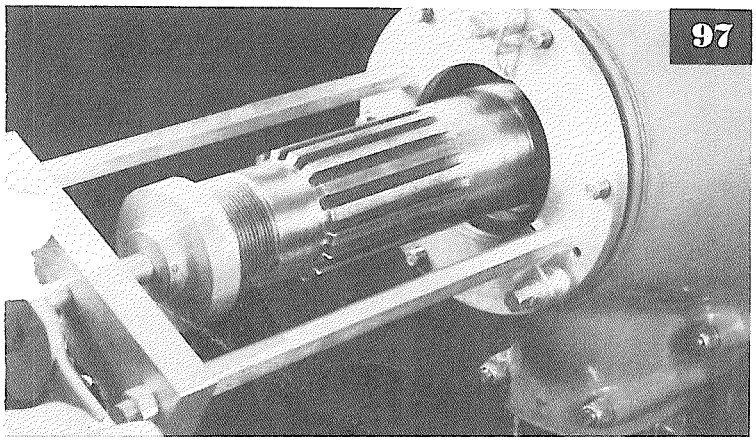
On earlier model engines, Puller, AT-140, cannot be used to remove the front crankcase cover, unless the cover has been reworked previously. On these engines use a fiber drift to loosen the front crankcase cover. Remove the front crankcase cover shim, being careful not to loosen the laminations when drawing shim over the studs. Remove the oil slinger from the crankshaft.

Attach Puller, AT-140, to the front crankcase studs and tighten against the end of crankshaft, pulling off the front crankcase. . . . . **98** Care must be taken not to let the gears drop out of the front crankcase or the main crankcase during this operation.

Remove upper front idler gear. Remove lower front idler bevel and spur gear assembly. It is not necessary to separate the lower front idler bevel gear and lower idler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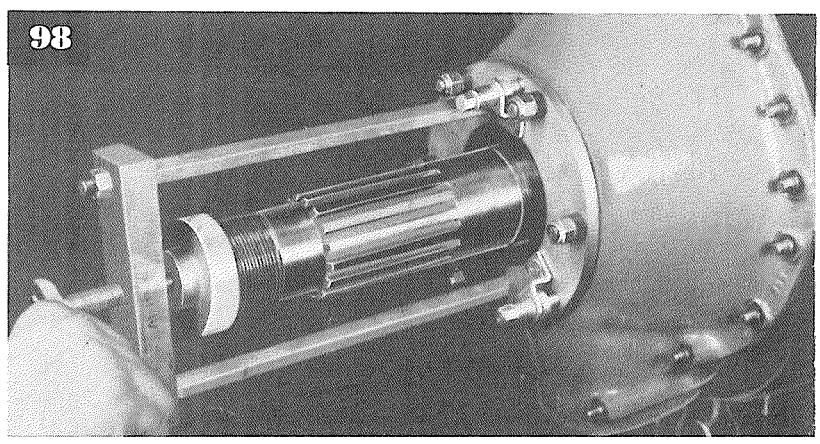
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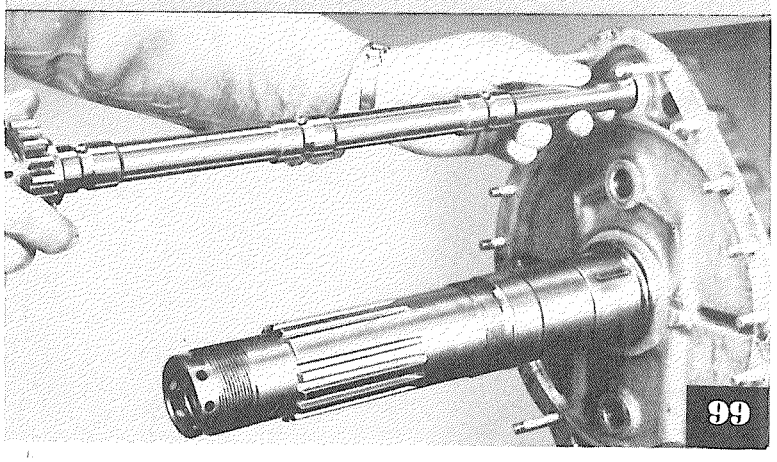
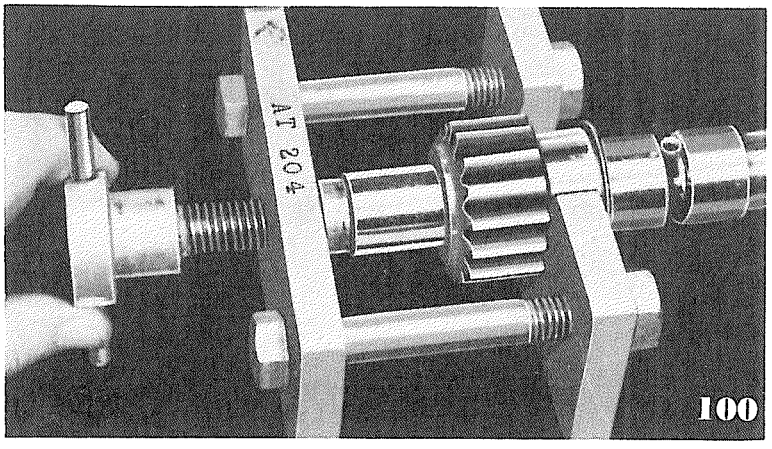




spur gear unless either gear is damaged. Remove and tag the lower front idler thrust washer.

Remove the thrust ball bearing from front crankcase, tapping the outer race of the bearing lightly with a fiber drift if necessary.

Accessory Drive Shaft

Remove the accessory drive shaft from the front of the crankcase main, taking care that the edges of the journals do not strike and damage the bearing surfaces as the shaft is drawn forward. **99**

Place the shaft front end up, in a vise equipped with copper jaws, being careful not to have the vise clamp on the shaft journals. Remove the nut retaining the accessory drive shaft front gear and remove the gear using Accessory Drive Shaft Front Gear Puller, AT-204. . . . . **100**

Remove the thrust plug in front end of shaft. Drill a hole in the front cup plug and remove the plug using a cup plug Puller, AT-379. Invert the shaft in the vise and remove the rear cup plug in the same manner.

Main Bearing Stud Nuts

Remove the 14 main bearing stud nuts. securing the crankcase upper to the crankcase lower.

Release the cradle lock pins of the engine assembly stand and return engine to normal position.

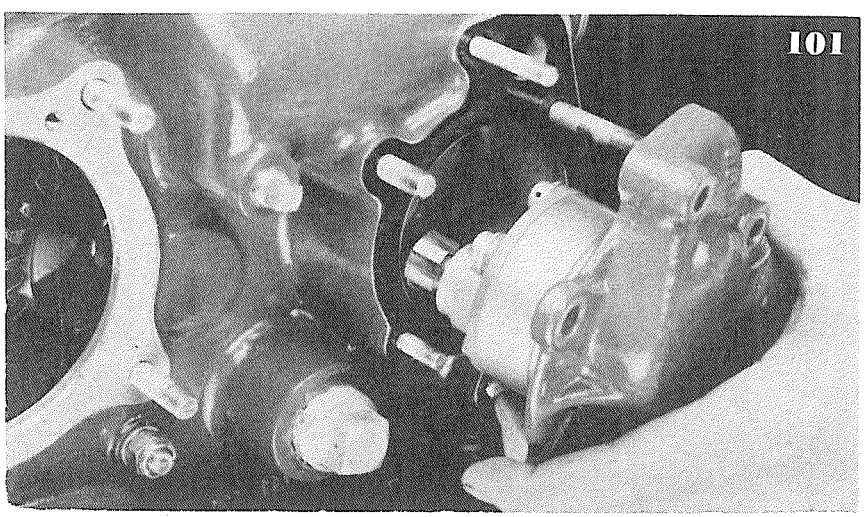
Pressure Oil Pump

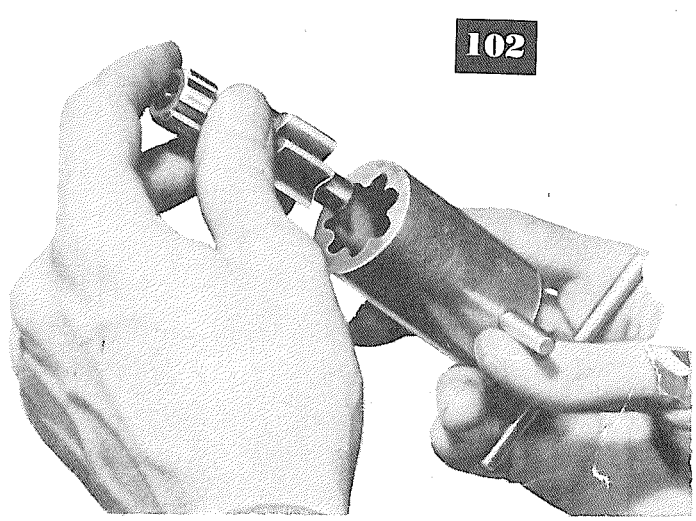
Remove the three 1/4 inch and three 5/16 inch self-locking nuts attaching the oil pressure pump to the rear crankcase. Tap the back of the pump lightly with a composition mallet and remove it. **101**

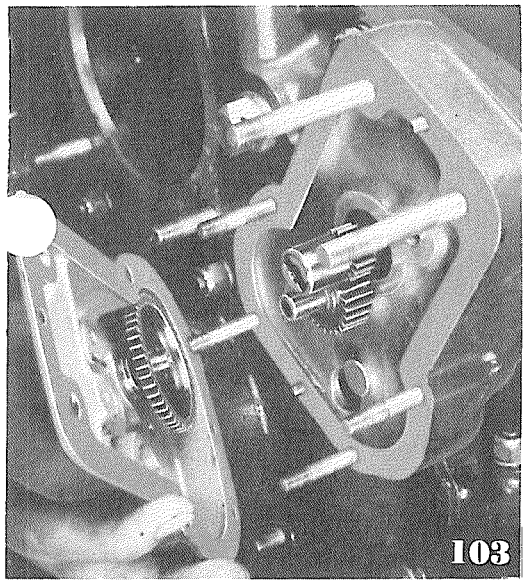
Remove the four cap screws holding the oil pressure pump cover to the pump housing and separate the housing and the cover. Should the housing and cover stick, they may be separated by tapping lightly with a composition mallet.

Remove the driven gear, take out and discard the cotter pin and remove the driven gear shaft. Remove the driving gear from the pressure oil pump shaft and pull the shaft out of the cover.

On the earlier type engines, the pressure oil pump drive gear was keyed to the drive shaft. On this type shaft the gear must be removed with pressure oil pump gear Puller, AT-207, ... **102**



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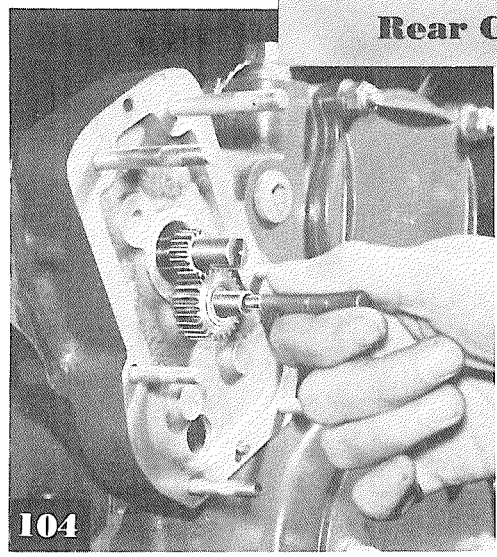
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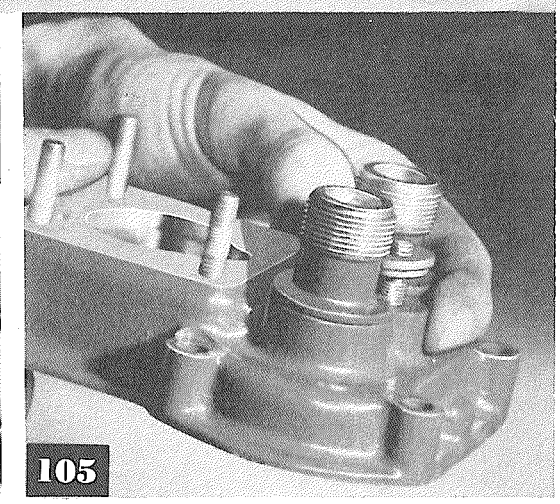
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and the key removed from the shaft. If the old style gear or shaft is damaged, both must be replaced by new gear, Part No. 9662, and a new shaft, Part No. 9669. Also, bushing, Part No. 1136, must be pressed into housing to compensate for the smaller diameter of the pilot on the new type shaft.

Remove oil pressure relief valve cap, locknut, gasket, adjusting screw, spring, plunger and the pressure oil relief valve seat.

Vacuum Pump and Tachometer Drive Housing

Remove the four ¼ inch and two 5/16 inch self-locking nuts attaching the vacuum pump and tachometer drive housing assembly to the rear crankcase and remove the housing using Vacuum Pump and Tachometer Drive Housing Assembly Puller, AT-188. . . . . **103**

Lift out the long and short tachometer drive gears with inserts, but do not remove the inserts.

Remove the tachometer drive idler gear shaft (which is pressed into the rear crankcase) using Tachometer Drive Idler Gear Shaft Puller, AT-392. . . . . **104**
Removal of the tachometer drive idler gear shaft will allow the idler gear to slip down clear of the sleeve on the vacuum pump drive gear.

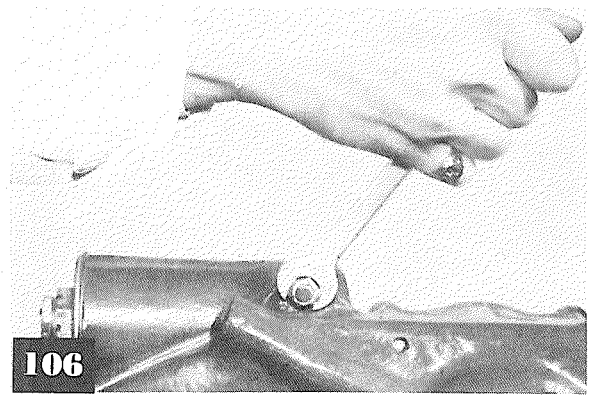
The tachometer gear adapters in the tachometer drive housing need only be removed if they are damaged. To do this, remove the self-locking nut and washer retaining the tachometer gear adapters and tap out the adapter. **105**

On engines using a single tachometer drive, one adapter has been replaced with a shouldered plug. Do not remove this shouldered plug.

Drive out the vacuum pump oil retainer from the tachometer drive housing.

Rear Crankcase Assembly

First loosen and then remove all nuts attaching the rear crankcase to the main crankcase. One nut is located on the forward face of the crankcase flange near the right hand magneto. **106**
Loosen the rear crankcase, tapping it with a fiber mallet if necessary, and remove it with care so that no gears drop out of the rear of the main crankcase. **107**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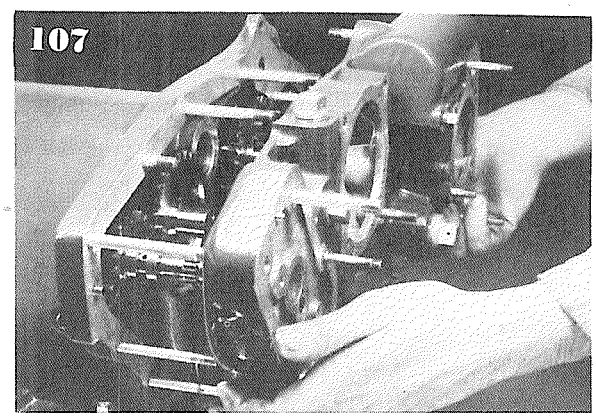
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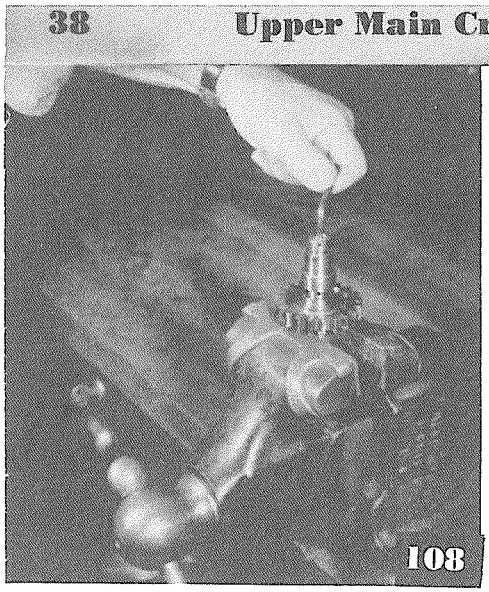
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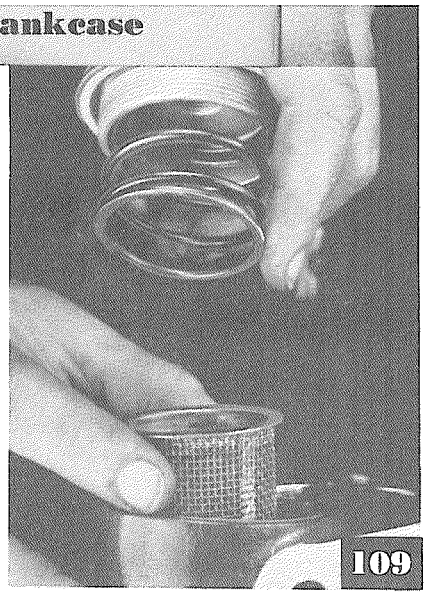
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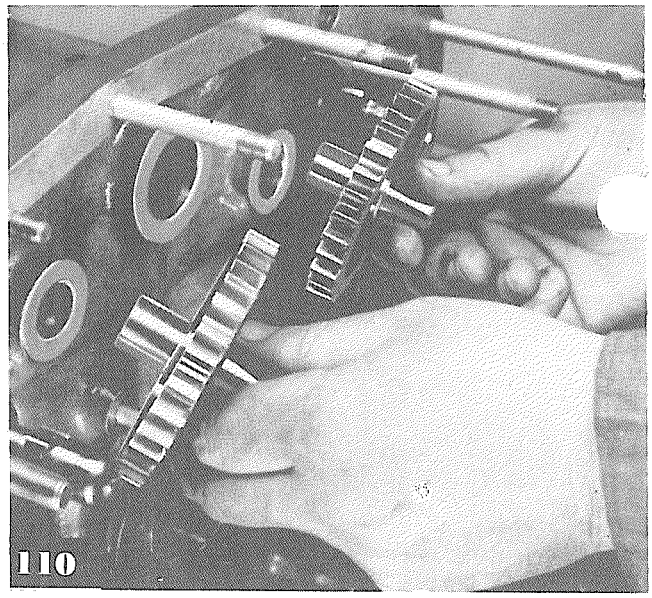
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Remove the two rear idler gears, the right magneto drive gear and the left magneto and vacuum pump drive gear. Place the magneto and vacuum pump drive gear in a vise equipped with copper jaws and using Wrench, AT-113, remove the 1/8 inch hollow hexagon pipe plug at the front of the gear. **108**

Remove the plug, gaskets, cover, spring and strainer from the large oil strainer chamber. **109**

Remove the magnet, gaskets and strainer from the small oil strainer chamber. Remove the two screws attaching the generator adapter plate to the crankcase rear and lift off. **110**

Remove the pipe plugs closing the ends of the oil passages.

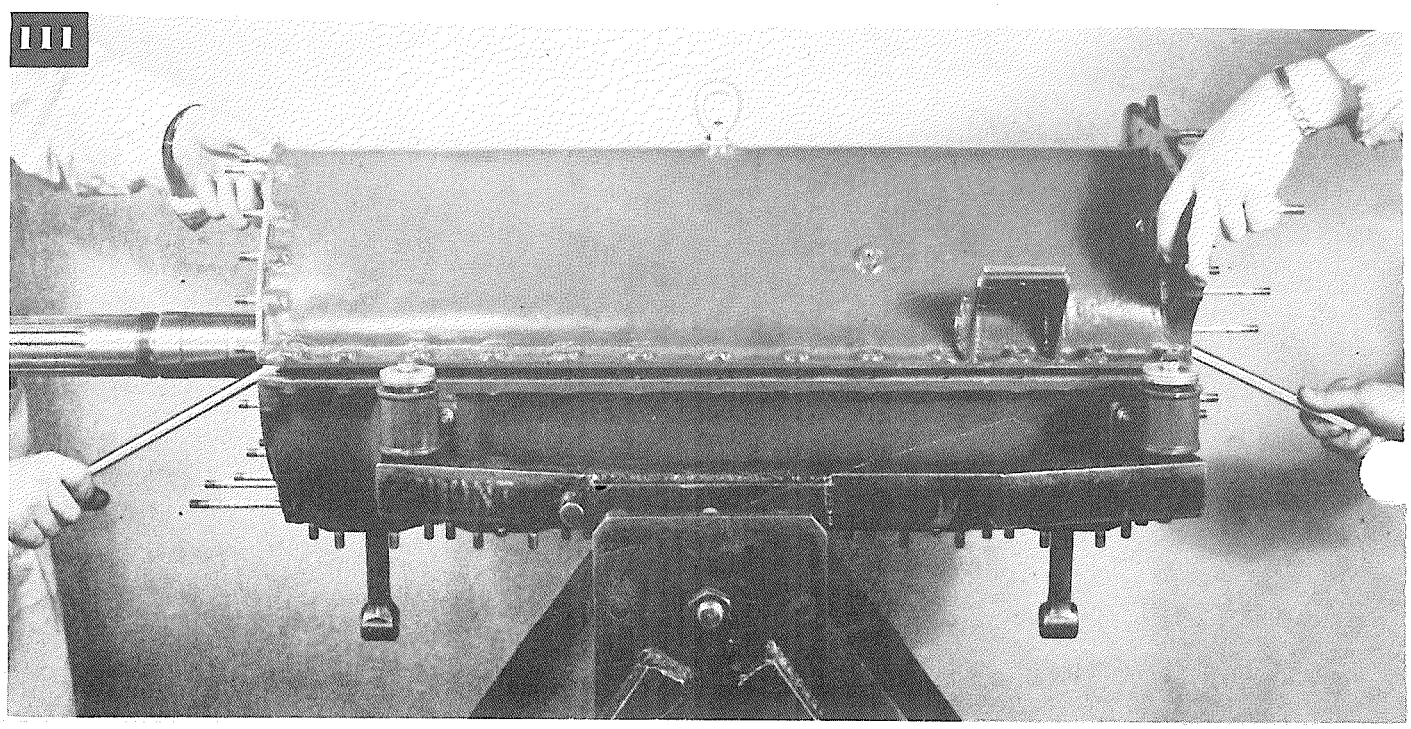
Upper Main Crankcase

First loosen and then remove all nuts and bolts in the flanges of the upper and lower halves of the main crankcase.

Separate the upper crankcase from the lower crankcase by inserting the Crankcase Separating Bars, AT-197, between the upper and lower halves of the front and rear webs. **111**

When removing the upper crankcase, care must be taken to prevent any of the main bearings from falling out.

Remove the upper halves of the main bearings from the upper crankcase making sure that they are clearly marked for location in the engine. Upper main bearing halves which are held to the crankshaft by oil suction can be freed by slightly rotating the shaft. . .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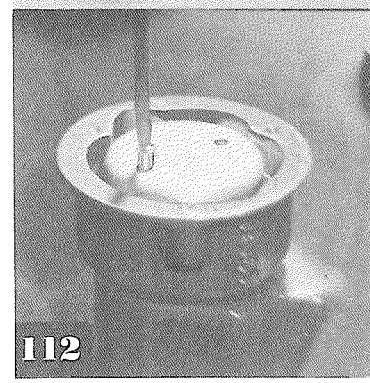
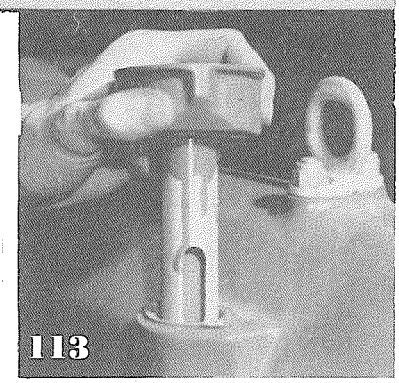
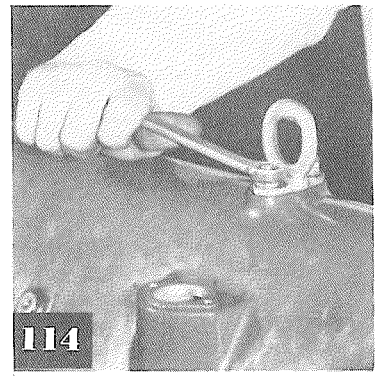
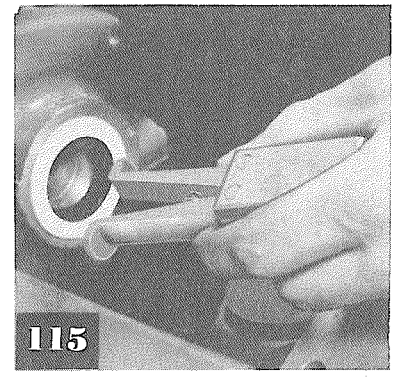
Remove the three screws and washers securing the outer breather cover and gasket to the breather body and lift off the cover and gasket. Do not attempt to remove the screen in the breather outer cover. Remove the two screws and washers holding the inner cover to the breather body and lift off the inner cover. **112**
Remove the two screws and washers holding the breather body to the crankcase and remove the breather body and gasket. . . **113**

Remove the two elastic stop nuts attaching the lifting eye to the pad on the crankcase upper and take off the lifting eye. **114**
Using a magneto drive oil retainer Remover, AT-202, remove the magneto drive oil retainers from the rear mounting pad on the upper crankcase. **115**







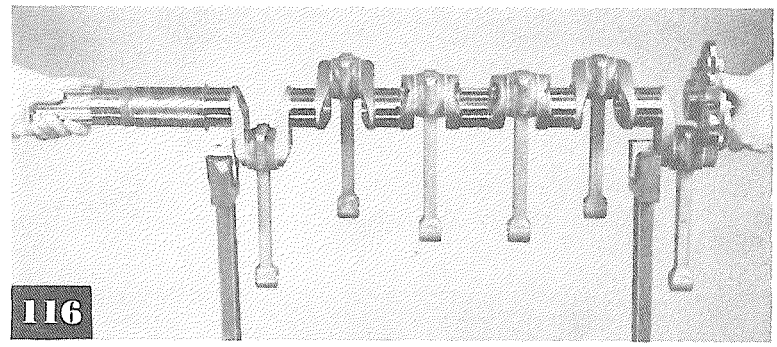


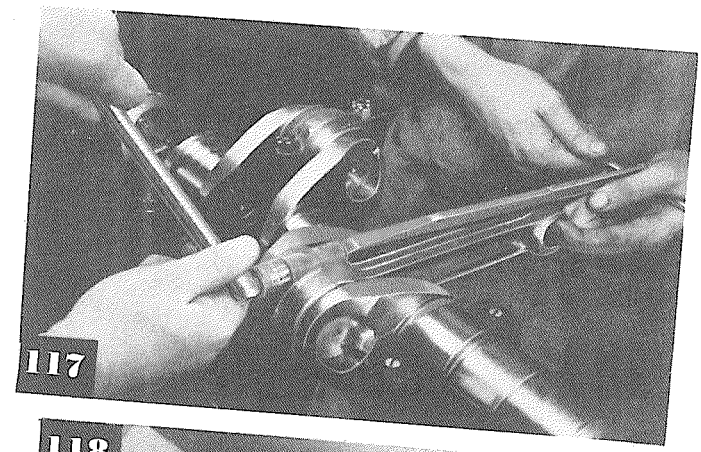
Crankshaft and Connecting Rod

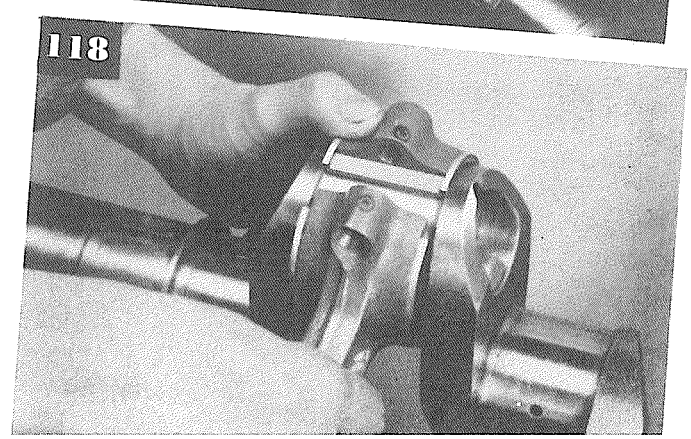
Lift the crankshaft with connecting rods attached, from the lower crankcase and place it on Crankshaft Assembly Stand, AT-190. . . . . **116**
Before removing the crankshaft, make sure that none of the main bearings are stuck to the shaft.

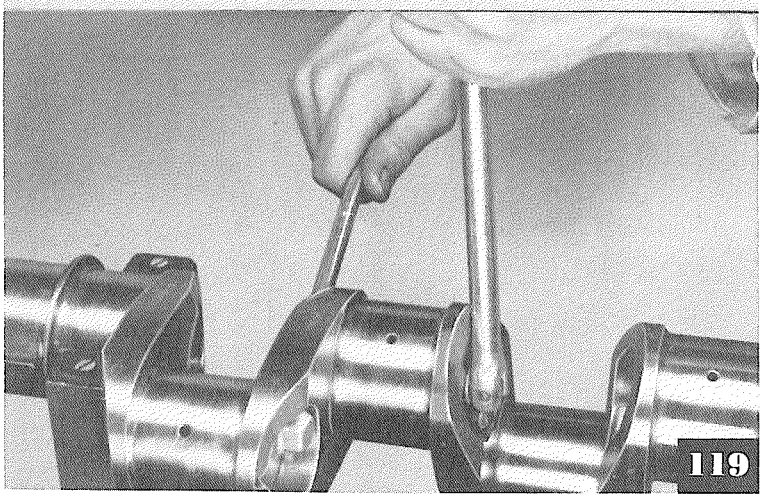
The crankshaft gear spacer and the crankshaft gear should now be removed by sliding them forward on the propeller shaft. Remove the crankshaft gear key, being careful not to damage the crankshaft.

Rotate crankshaft to the position where No. 1 and No. 6 crankthrows extend vertically upward. Loosen the connecting rod nuts attaching No. 1 connecting rod bearing cap to the rod, using Connecting Rod Wrench, AT-192, on the nuts and connecting rod Screw Driver, AT-193, to hold the slotted head bolts. Remove the nuts and then remove the bolts, driving them out with an aluminum or brass drift while holding the connecting rod and bearing cap in place on the crankshaft. **117**
Remove the rod and cap from the crankshaft and remove the bearings from the rod and cap. When removing the bearings, make sure that they are clearly marked as to location in the engine. **118**
Repeat operation to remove No. 6 bearing cap, rod and bearings.









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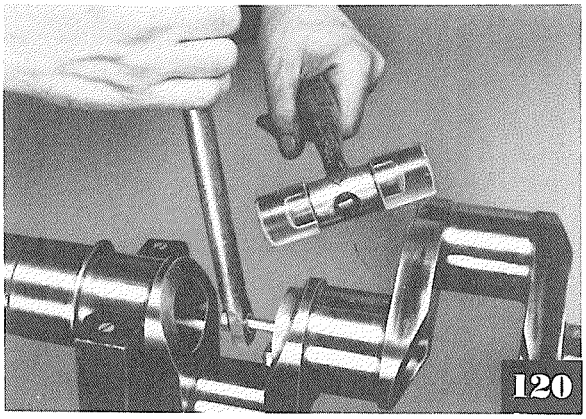

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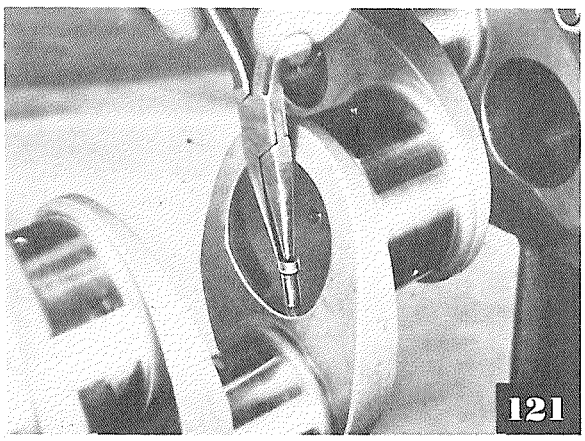
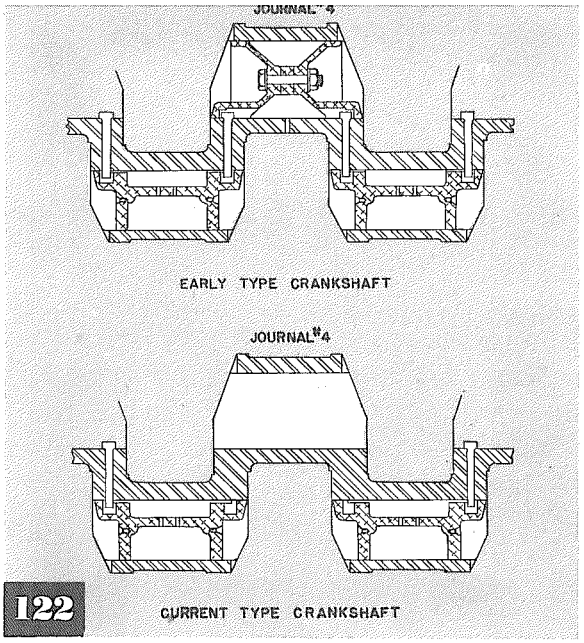


121

Rotate crankshaft as required and remove all other bearing caps, rods and bearings following the same procedure.

Take out the cotter pins in the ends of the bolts holding each pair of large crankshaft oil plugs in the main journals. When using a pair of pliers or cutters to remove the cotter pins, care must be taken not to damage the edge of the journal bore by pressing against it.

Loosen and remove the nuts, using two socket wrenches, ... **119**



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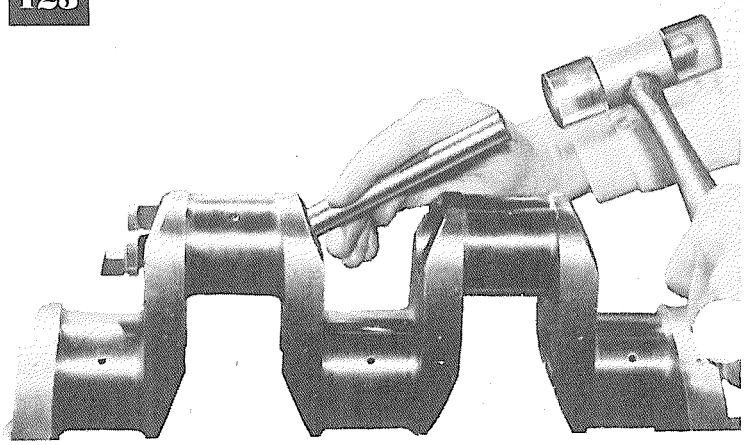


then remove the bolts. Remove the large crankshaft plugs, using Puller, AT-404. . . . . **120**

When all the large crankshaft plugs have been removed, the hollow dowel pins in the crank cheeks should be removed using a pair of long nose pliers. **121**

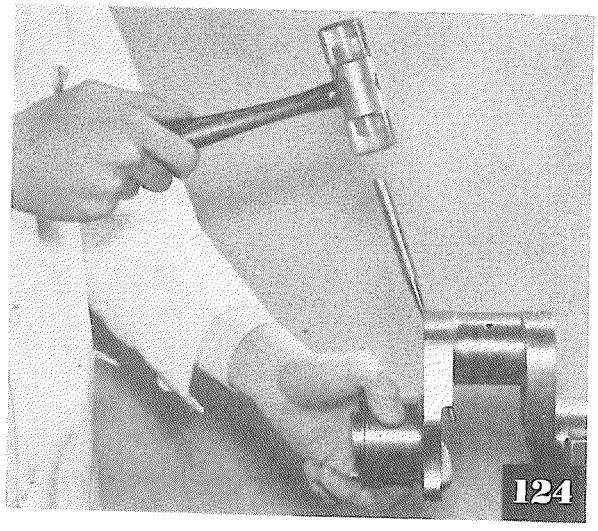
On earlier engines, a spacer is installed between the two large crankshaft plugs located in the number four crankshaft journal. On current model engines, the crankshaft assembly differs from the old style only in that there is no radially drilled hole in the number four crankshaft journal, and there are no dowels in the forward cheek of number three crankthrow. Also the large crankshaft plugs, spacer and attaching parts have been eliminated from number four crankshaft journal. **122**

The small crankshaft plugs should now be removed by tapping them out with a fiber drift. **123**

The crankshaft damper assembly must be disassembled at each overhaul for inspection. The damper plate nuts and the damper bearing nuts are safetied with tapered pins. It is impossible to properly realign the tapered pin holes once the nuts have been removed from the bolts. For this reason the damper bolts should be discarded at each overhaul. This makes it unnecessary to drill out the tapered pins. The quickest way to remove the nut is to shear the tapered pins by unscrewing the nuts with two socket wrenches.

Remove the front and rear damper weights, rings, spacers and bearings. Tag all for exact position except the bearings which must be discarded and replaced upon reassembly. Remove the four crankshaft damper plate bolt nuts.

Tap out pin locating the balancing plug in No. 1 crankpin . . . . . **124** and remove balancing plug.



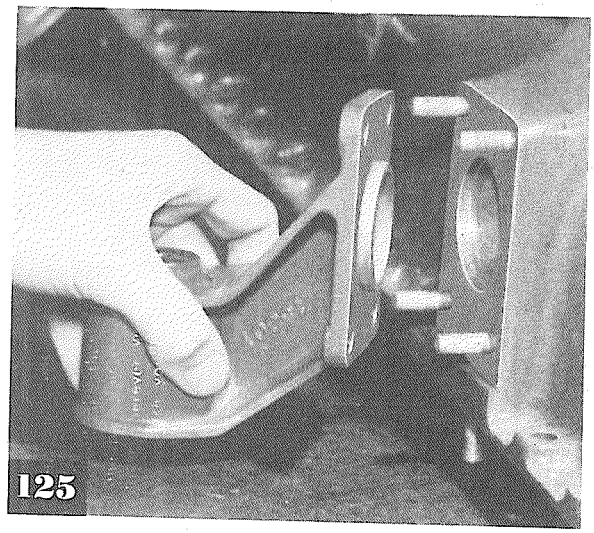
Do not remove the cup plug in the rear end of the crankshaft nor the starter driving jaw at this time. Should subsequent inspection indicate replacement necessary, refer to Chapter IV for detailed instructions.

Lower Main Crankcase

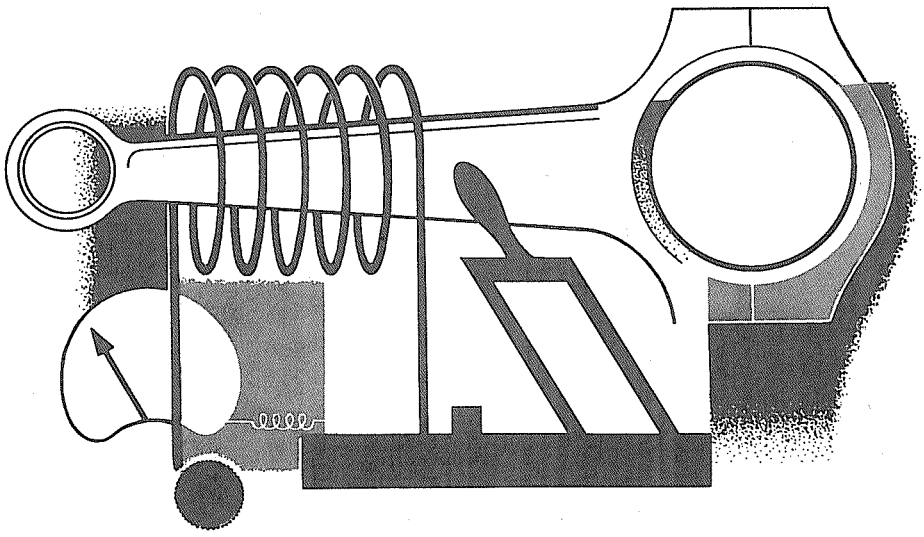
Remove the self-locking nuts and washers attaching the mounting brackets to the lower crankcase and remove the engine mount brackets. **125**
Remove the four bolts from the mounting brackets holding the lower main crankcase to the engine assembly stand and lift off the lower main crankcase.

Remove the lower halves of the main bearings from the lower half of the crankcase making sure that they are clearly marked for location in the engine.

Remove the engine mount brackets from the crankcase. Place the engine mounting brackets in an arbor press and press out the bushings.



CHAPTER III



INSPECTION

MAGNAFLUX INSPECTION

Principle

The magnaflux method of inspection is a procedure by which parts made of ferrous metals are inspected by magnetization. It is a well known fact that a bar magnet will attract ferrous metals at the ends where the lines of force pass through the surface of the magnet. However, there is little magnetic attraction on the flat sides of the bar magnet where the lines of force flow parallel to the surface. **132**

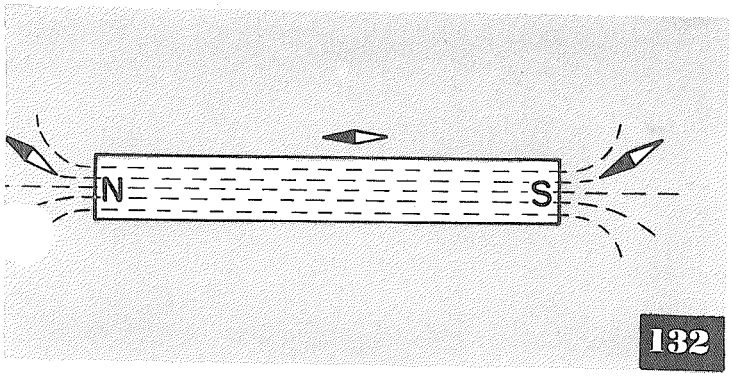
If a crack exists at right angles to the lines of force in the bar magnet, the lines of force will tend to bridge the gap by passing around the interruption. When this happens, the two edges of the crack will assume north and south polarity. **133**

This interruption in the magnetic flow is not visible to the naked eye but when such an interruption is brought in contact with a visible medium, such as fine iron powder, the powder will pile up along the edge of the crack and will thus become visible as a black line.

Several methods of magnetization are used in magnaflux inspection. The most commonly used method makes use of the fact that a circular magnetic field will develop about any conductor of electricity. The part to be magnetized is mounted between two contact heads and a high amperage, low voltage electrical current is passed through the part to be inspected. This will set up a circular magnetic field around the outside of the part which will tend to show up cracks running paralled to the longitudinal axis of the part. **134**

If a part is of such a shape that it cannot readily be mounted between the contact heads, such as a ring shaped bearing race, it may be suspended over a copper rod mounted between the contact heads. When the current is passed through the copper rod, circular magnetism will be developed around the outside of the rod and the same magnetism will be induced in the ring over the rod. **135**

A different method of magnetizing consists of placing a part inside a coil through which the high amperage, low voltage cur-



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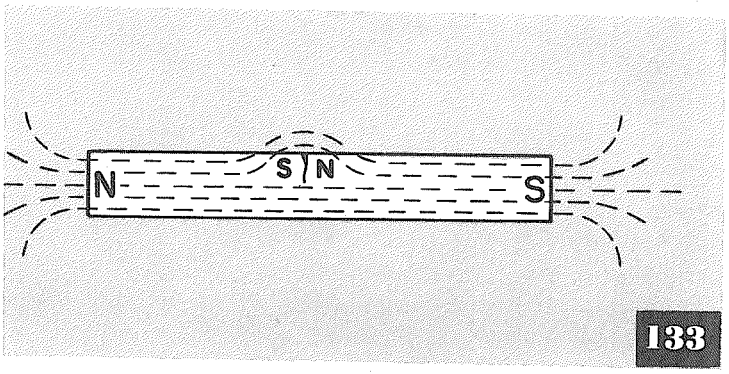

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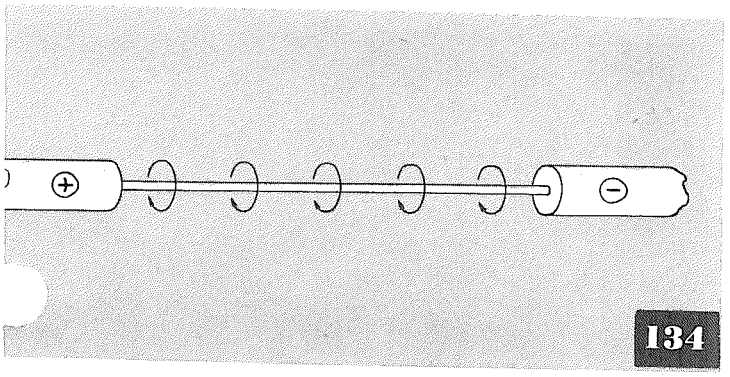

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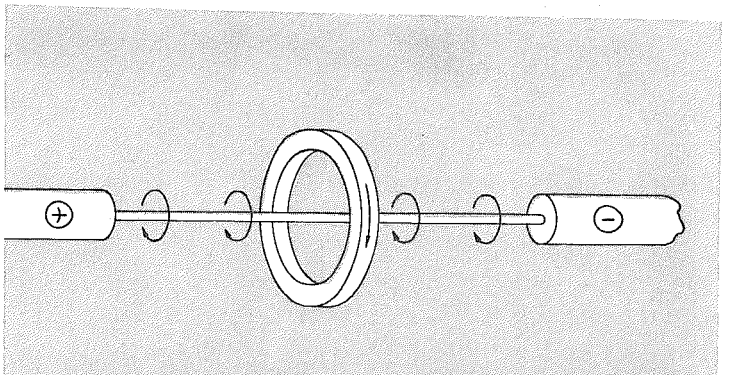

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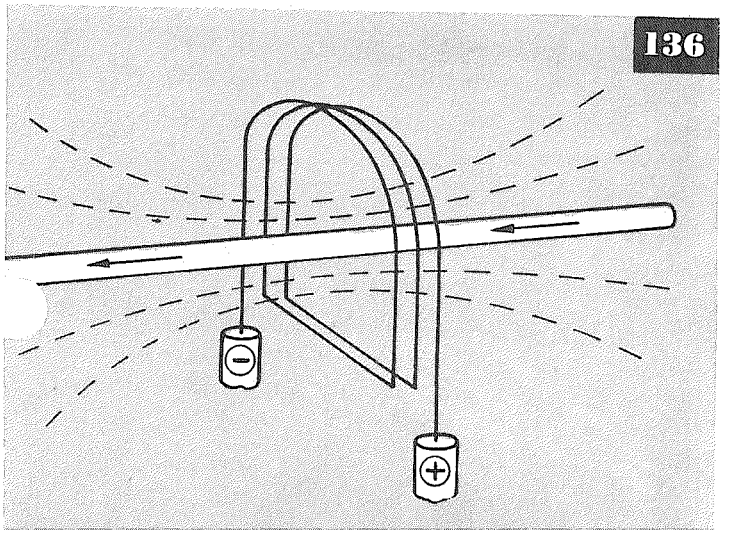
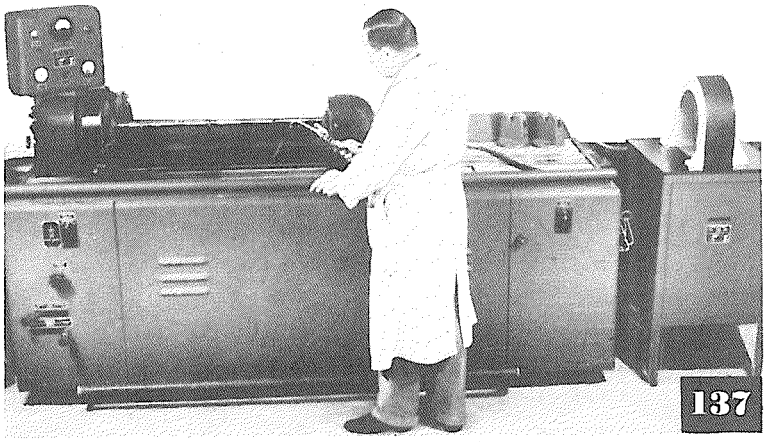


rent is passed. The magnetic lines of flux will now flow through the center of the coil and any object placed inside the coil will be magnetized in a direction at right angles to the plane of the coil. 136

Cracks are shown up best if they run at right angles to the direction of the magnetic lines of flux within the part. As the angle between the lines of flux and the direction of the crack decreases, the indication will gradually become weaker until at an angle of about 30° to the lines of flux, it will no longer be apparent. Experience has shown that in some parts, cracks can only be expected in one certain direction and in that case it is only necessary to magnetize the part at right angles to this direction. However, in most parts a crack may be found running in any direction and it is, therefore, necessary to magnetize the part in two or more different directions. In this case it is very important to completely demagnetize the part before magnetizing it again in a different direction. It is also important to demagnetize each part after inspection has been completed. Parts can be magnetized by either alternate or direct current. However, demagnetization can be carried out satisfactorily only with alternate current.

Equipment

The type of magnaflux machine most commonly used for aircraft engine overhaul inspection is of the horizontal type. The working platform of the machine is at bench height while the base below houses the various controls and automatic timing devices, the tank and pump for the inspection medium and, in the case of direct current equipment, the source of power supply consisting of batteries or a rectifier. On top of this base are mounted two contact heads, one of which is in a fixed position while the other one is movable along a track extending the entire length of the machine. The top of the machine also carries a movable coil which can be moved on the central track and which fits over the fixed head when not in use. Current is applied by a foot switch extending the length of the front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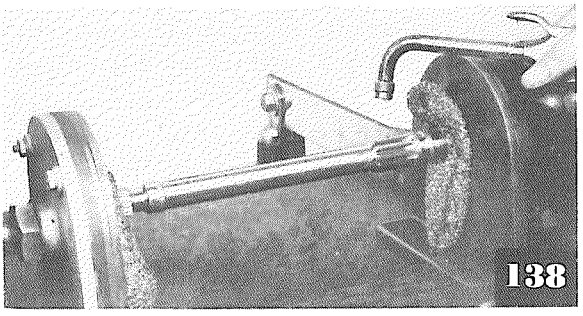
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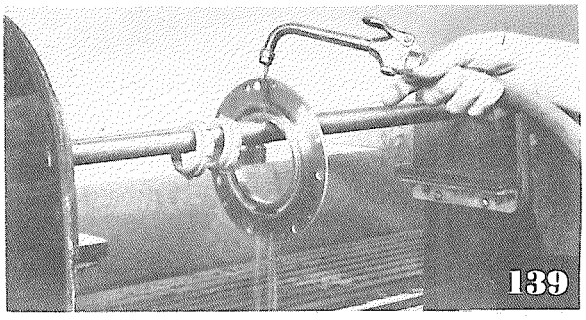
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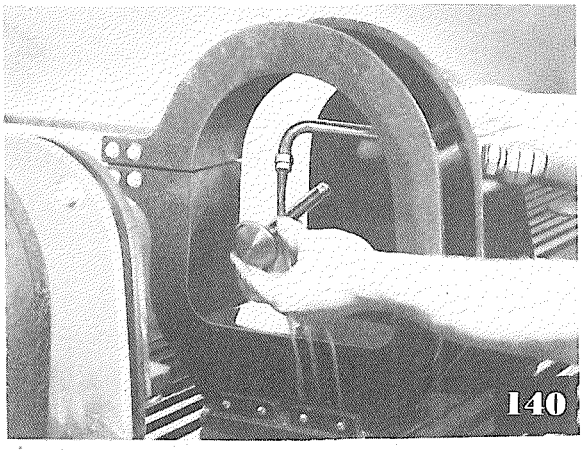
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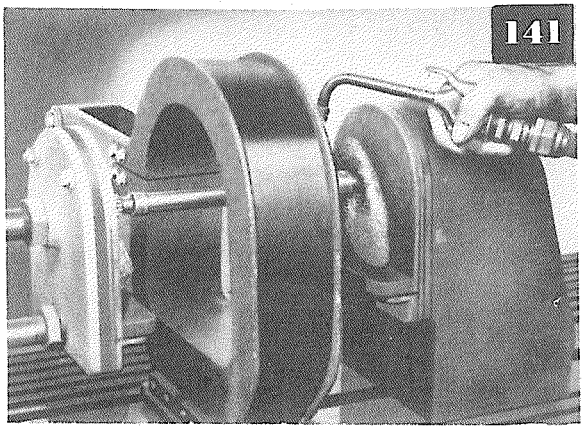

141

of the machine. Controls are also provided to adjust the current and to start and stop the pump which circulates the inspection medium. 137

In order to magnetize a part such as a shaft with circular magnetism, one end of it is placed against the stationary contact head and the movable contact head is then moved up against it. The current is then adjusted to the correct value and the foot switch is depressed. As this switch is depressed, the contact plate in the stationary head is automatically forced against the end of the part between the heads by compressed air. . 138 This insures that good contact will be made between the heads and the ends of the part which will prevent arcing and burning of the parts. Ring shaped parts are placed over a copper or bronze rod either alone or several at a time. This rod is then clamped between the contact heads and the current is passed through the rod as previously described. 139

Small parts which have to be magnetized in the coil can be held in the coil by hand. 140

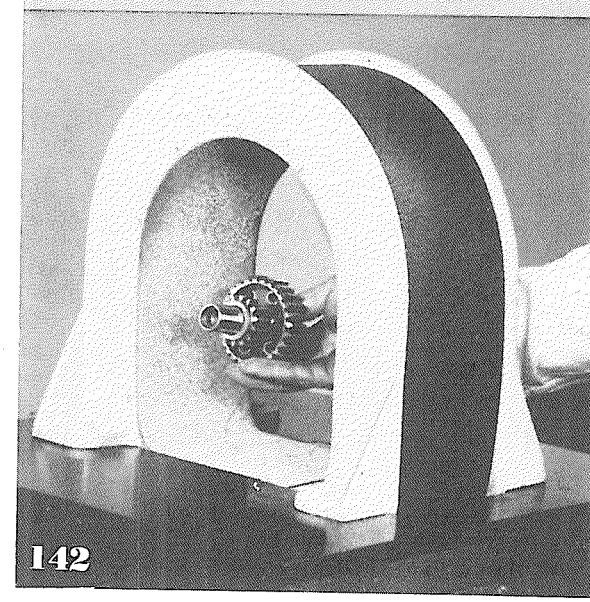
In doing this, the part should be held close to the inner edge of the coil where the magnetic lines of force are strongest. Parts which are heavy or difficult to hold can be clamped between the heads or mounted on a rod in order to support them, after which the current is passed through the coil around the part. 141

The inspection medium used with this type of equipment consists of fine iron oxide powder suspended in some non-inflammable liquid such as safety naphtha. The iron oxide may be either black or red in color. Black powder will give a more clearly defined indication. Red powder is not so easily visible but its use is preferable on parts which may not have been cleaned completely and may still contain a few streaks of black carbon.

With alternating current equipment the same coil which is used to magnetize parts can also be used to demagnetize parts. In the case of a direct current set, a special alternating current demagnetizing coil is necessary. To demagnetize a part, the alternat-

ing current in the coil should be turned on and the part should be moved from a point about 18″ in front of the coil through the coil to a point 18″ behind the coil at a steady, even speed of about twelve feet per minute for large irregularly shaped parts and about twice this speed for small parts which are more easily demagnetized.

It is extremely important that parts be completely demagnetized before being installed in an engine as otherwise they will attract any small steel particles which may be present in the engine, which may cause considerable damage to bearings. To test parts for demagnetization, they should be passed over a compass needle. The compass needle should deflect not more than 3° at a distance of 6″ from the part. If a part is not completely demagnetized after being passed through the coil it should be passed through the coil again, this time holding it in a different position. **142**

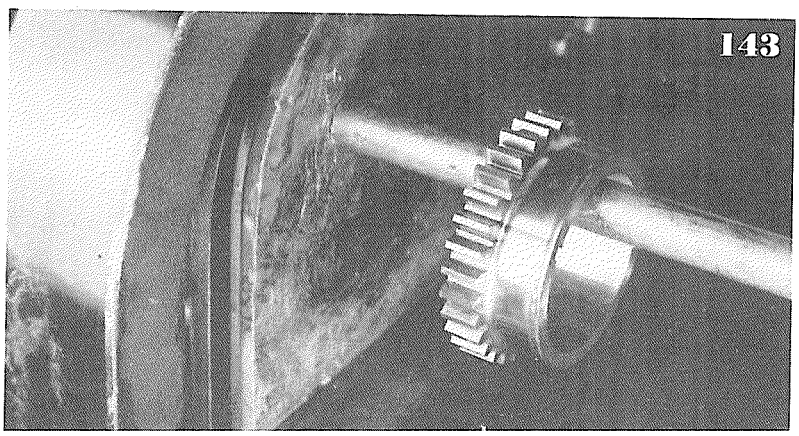

142

Interpretation of Results

The evaluation of magnaflux indications has caused many controversies and no definite rules concerning their interpretation can be given. This type of inspection relies to a high degree on the skill of the operator and it is suggested that the operation of this equipment be confined to as few individuals as possible who will thus be able to acquire the necessary skill and experience to satisfactorily use this inspection method. As a general rule, all indications should be examined very carefully. In many cases close inspection will show that a number of these indications can be dismissed as unimportant. It must be remembered that forging laps and seams will cause magnaflux indications which in themselves are of no importance, except if they appear in highly stressed areas where they may give rise to fatigue cracks.

One of the most common causes for apparent magnaflux indications which are not necessarily important is the application of too high a magnetizing current. A table of the correct amperage to be used in magnetizing individual parts is given at the end of this section. These values may be exceeded if it is desired to find the extent of an indication which does not show up very well during normal inspection. However, it should be remembered that almost any part will show magnaflux indications provided a high enough current is used, and indications produced by currents in excess of those given in the table need not normally be considered as important.

In some instances indications may be caused by the peculiar shape of the part being inspected. For instance, a sudden reduction in cross section, such as would happen where a keyway is cut into a gear, will show a magnaflux indication which is merely a concentration of lines of force and does not necessarily indicate a crack. **143** and **144**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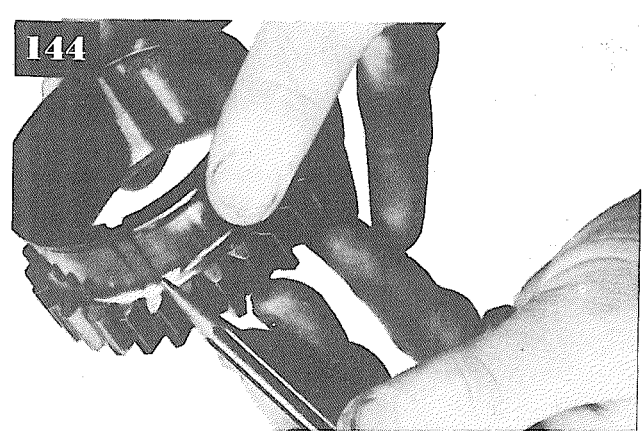
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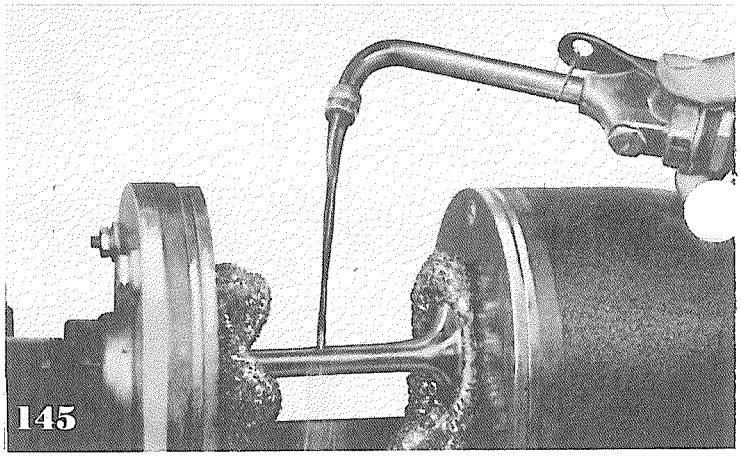
The same amount of current will give a stronger indication with the continuous method than with the residual method. In many cases it is advisable to recheck any indications found with the continuous method, using the residual method. If the same indication does not reappear when using the residual method, using the correct current values given in the table, it is most likely that the indication is not serious enough to warrant rejection of the part.

Special Instructions

Satisfactory lighting is one of the most important requirements for good magnaflux inspection. A fluorescent fixture suspended about 4 feet above the top of the machine and with the tubes running at right angles to the tracks for the movable head is considered most satisfactory. A high power magnifying glass or binocular microscope is also required. As exposure to the fine iron powder suspended in the liquid is injurious to the skin, the operator's hands should be protected with a protective chemical compound marketed by the manufacturer of the magnaflux equipment. Rubber gloves are not recommended.

For a satisfactory magnaflux inspection it is necessary that all parts be completely disassembled. Gears should be removed from their respective shafts, connecting rod caps should be removed from the rods, damper adapters must be removed from the crankshaft, etc.

Anti-friction bearings may not be magnafluxed because it will be impossible to completely remove the iron powder after inspection. Rocker arms with needle bearings installed may not be magnafluxed for this reason. Where parts with internal passages, which are not easily cleaned, are being magnafluxed, any oil holes leading into these passages must be closed off with heavy grease or wooden plugs so that the inspection medium cannot enter the part.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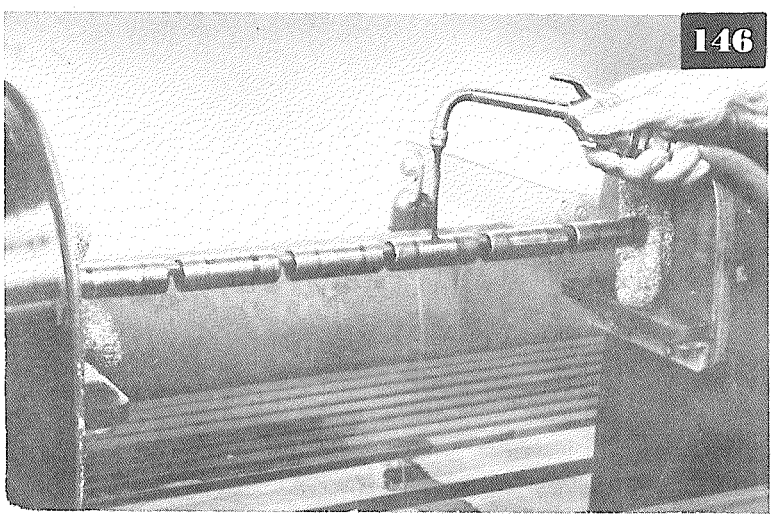
All parts to be magnaflux inspected must be perfectly clean. Any scores in polished surfaces which may show up as indications should be polished out.

The contact surfaces of the two contact heads are covered with lead plates which will melt before any part becomes seriously burned. However, these lead plates quickly become mutilated in service and will then no longer serve their purpose. It is, therefore, recommended that pads of copper braid be placed between the heads and the part to be magnafluxed. **145**

Procedure

When a number of parts are being magnetized on a rod at the same time, they should be separated so that they will not touch each other as otherwise they may be magnetized unevenly. **146**
However, when these same parts are to be magnetized with the coil, while still suspended on the rod, they must be placed firmly together. **147**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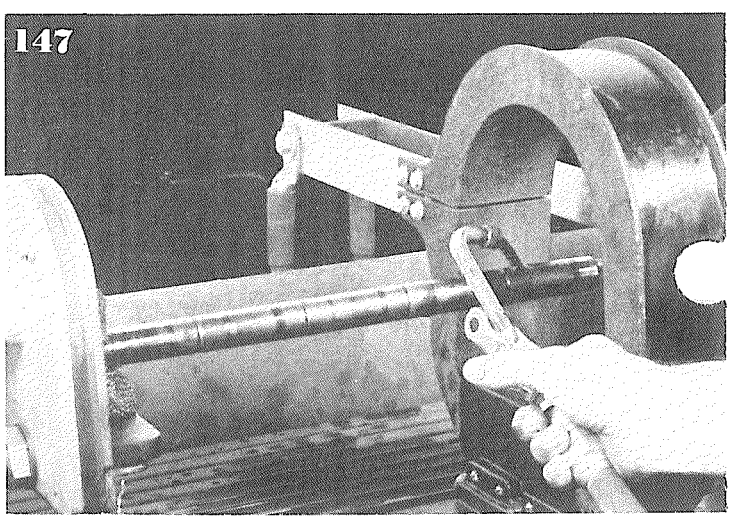
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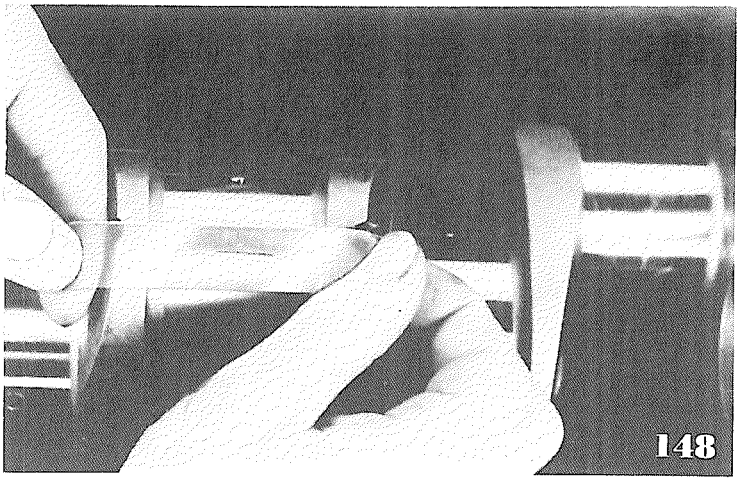

148

The reason for this is that as the current flows through the coil each magnetized part will become an individual magnet which is very strongly attracted to the adjacent one. Where parts are not already in contact they will strike each other with a terrific force as soon as the current starts to flow.

If slight indications are found which are border line cases it may be advisable to try to stone out the indication if it is not in a highly stressed area. Very often an indication which is quite pronounced will disappear if the surface on which it appears is polished down .003″ to .004″. Naturally such stoning may only be done if it does not materially effect the strength of the part at that point and the area must again be magnaflux inspected after the rework operation.

In some cases it may be considered desirable to keep a record of the exact appearance of an indication which in itself is not considered cause for rejection. To do this the magnaflux pattern in the area in question should be allowed to dry. After this, a strip of transparent scotch cellulose tape should be pressed down evenly on the indication. 148

When this tape is removed, the iron particles forming the pattern will cling to it. The piece of tape with the pattern on it can now be pasted on the inspection sheet where it will form a permanent record for future reference. 149

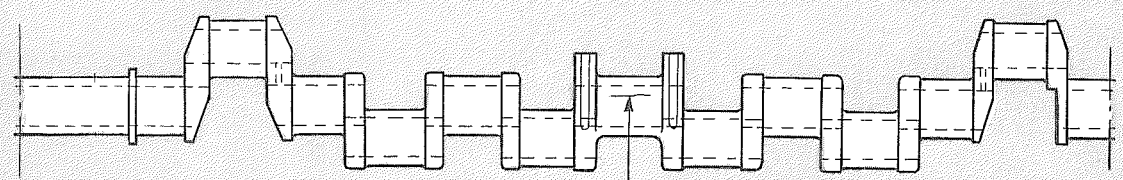
If at the next overhaul, it is found that the indication has increased in size, it means that the part is failing progressively and should not be used again.

After magnaflux inspection has been completed and all parts have been completely demagnetized, the parts should be thoroughly washed and dried and should then immediately be covered with a protective coat of oil to prevent corrosion.

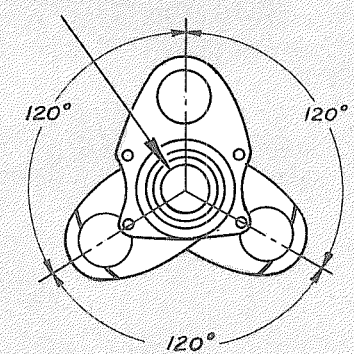
Magnaflux all of the following stressed steel parts in accordance with the specifications and instructions given in the following table.

149

CRANKSHAFT MAGNAFLUX INSPECTION REPORT



ENGINE SERIAL NO.: 745
CRANKSHAFT SERIAL NO.: R-1603
TOTAL TIME: 623:30
LOCATION: No. 4 Journal
NUMBER OF INDICATIONS: 1
LENGTH: 15/16"
DIRECTION OF CRACK: Parallel To Crankshaft Center Line
REMARKS: Forging Indication Shaft Returned To Service
DATE: 2-15-44
INSPECTOR: W. F. Smith



Magnaflux Inspection Instructions for Various Steel Engine Parts

PART	CURRENT	METHOD
GEARS:		
Crankshaft Gear	2500 Amps.	On rod and in coil
Camshaft Front Gear	1800 Amps.	On rod and in coil
Accessory Drive Shaft Front Gear	2000 Amps.	On rod and in coil
Accessory Drive Shaft Rear Gear	1500 Amps.	On rod and in coil
Vertical Drive Shaft Upper Gear	2000 Amps.	On rod and in coil
Vertical Drive Shaft Lower Gear	2000 Amps.	On rod and in coil
Upper Front Idler Gear	2000 Amps.	On rod and in coil
Lower Front Idler Spur Gear	2000 Amps.	On rod and in coil
Lower Front Idler Bevel Gear	2000 Amps.	On rod and in coil
Rear Idler Right Hand Gear	2000 Amps.	On rod and in coil
Rear Idler Left Hand Gear	2000 Amps.	On rod and in coil
Magneto Drive Gear	2000 Amps.	On rod and in coil
Magneto and Vacuum Pump Drive Gear	2000 Amps.	On rod and in coil
Tachometer Drive Idler Gear	1500 Amps.	On rod and in coil
Tachometer Long Gear	1000 Amps.	By hand against inner wall of coil
Tachometer Short Gear	1000 Amps.	By hand against inner wall of coil
Pressure Oil Pump Drive Gear	1500 Amps.	On rod and in coil
Pressure Oil Pump Driven Gear	1500 Amps.	On rod and in coil
Scavenge Oil Pump Drive Gear	1500 Amps.	On rod with blind and against head and in coil
SHAFTS:		
Crankshaft	3500 Amps.	Between heads and with coil
Camshaft	2500 Amps.	Between heads and in coil
Accessory Drive Shaft	2500 Amps.	Between heads and in coil
Vertical Drive Shaft	2000 Amps.	Between heads and in coil
Pressure Oil Pump Drive Shaft	1500 Amps.	In coil
Pressure Oil Pump Driven Gear Shaft	1500 Amps.	In coil
Scavenge Oil Pump Drive Shaft	1500 Amps.	In coil
Scavenge Oil Pump Driven Gear Shafts (2)	1000 Amps.	On rod and in coil
Tachometer Idler Gear Shaft	1000 Amps.	On rod and in coil
MISCELLANEOUS:		
Crankshaft Thrust Bearing Nut	2500 Amps.	On rod and in coil
Crankshaft Gear Spacer	2500 Amps.	On rod and in coil
Crankshaft Plug	2500 Amps.	Between heads
Crankshaft Damper Plate	2500 Amps.	Between heads and in coil
Crankshaft Damper Weights, Front and Rear (6)	2500 Amps.	On rod and in coil

PART	CURRENT	METHOD
MISCELLANEOUS:—continued		
Crankshaft Plug Hollow Dowels (10)	1000 Amps.	String together on wire and hold in coil
Connecting Rods (6)	2500 Amps.	Between heads with bar through piston pin hole and in coil
Connecting Rod Bearing Caps (6)	2500 Amps.	On rod (through bolt holes) and in coil
Connecting Rod Bolts (12)	1500 Amps.	Between heads and in coil. Screw two bolts into one nut.
Connecting Rod Bolt Nuts (12)	1500 Amps.	On rod and in coil
Piston Pins (6)	2500 Amps.	On rod and in coil
Camshaft Nut	1500 Amps.	On rod and in coil
Intake Valves (6)	2000 Amps.	Between heads and with coil
Exhaust Valves (6)	3500 Amps.	Between heads and in coil. Continuous method only as this part cannot be permanently magnetized
Valve Washers, Upper (12)	1800 Amps.	On rod and in coil
Valve Washers, Lower (12)	1800 Amps.	On rod and in coil
Valve Washer Locks (24)	1000 Amps.	In coil
Valve Rockers Assemblies (12)	2000 Amps.	On rod and in coil
Valve Rocker Hub Shafts (12)	1000 Amps.	On rod and in coil
Valve Rocker Adjusting Screws (12)	1000 Amps.	In coil only. Do not place between heads
Valve Rocker Adjusting Screw Nuts (12)	1000 Amps.	In coil
Scavenge Oil Pump Drive Adapter	1500 Amps.	On rod and in coil
Pressure Oil Relief Valve Seat	1500 Amps.	On rod and in coil
Pressure Oil Relief Valve Screw	1500 Amps.	On rod and in coil
Magneto Drive Couplings (2)	1500 Amps.	On rod and in coil
Magneto Driven Couplings (2)	1500 Amps.	On rod and in coil

GENERAL INSPECTION

This section contains detailed instructions on that part of the general inspection procedure which is peculiar to the Ranger 6-440C series engines. The inspection of all parts not specifically described, will be in accordance with generally accepted practices.

Front Crankcase

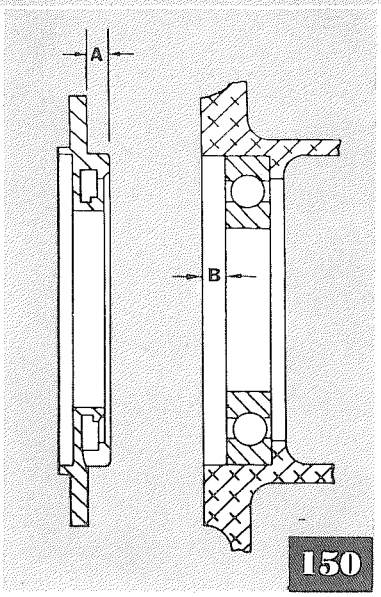
Examine the front crankcase section for nicks, dents, cracks or other signs of damage, giving special attention to the parting surfaces and stud holes.

Inspect all studs for condition and tightness, also for stretch by measuring the length of the protruding section with a depth scale.

Examine the interior and end faces of the bearing bosses for signs of scoring or excessive wear. Using an inside micrometer, measure the inside diameter of the bearing bosses.

Inspect the vent plug and hole for condition of threads and the plug for condition of plating.

Measure the journals of the upper front idler gear, the lower front idler spur gear, and the lower front idler bevel gear.



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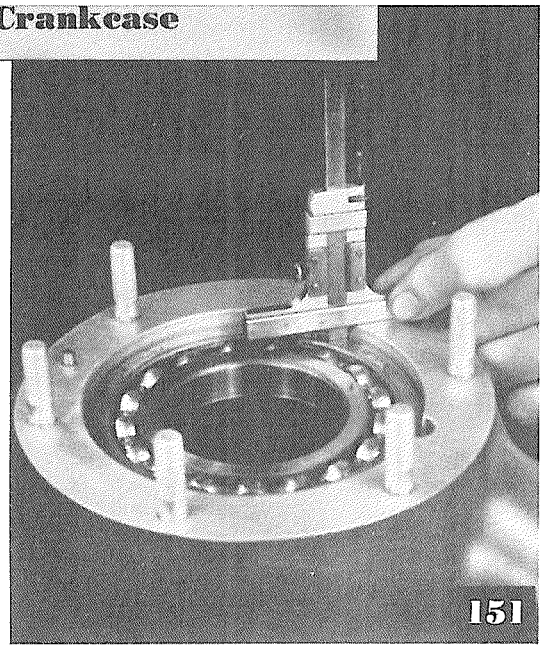
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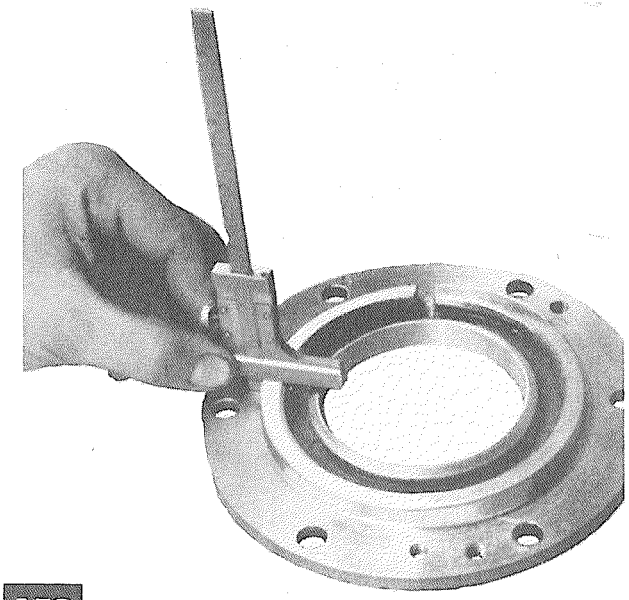
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Examine the gear teeth for indications of improper mesh, excessive wear, burrs, pits, cracks or scratches. If the lower front idler bevel gear was removed, inspect the keyway for condition.

Examine the front crankcase cover for nicks, dents, scratches, cracks or other signs of damage giving special attention to the parting surfaces and stud holes; also for signs of interference between the crankshaft oil slinger and the cover. Check fit of thrust bearing in cover.

Early engines were equipped with a front crankcase cover in which there is no provision for adjustment of the clamping action on the outer race of the thrust bearing. All other engines are equipped with a laminated shim between the front crankcase and the cover, which provides for this adjustment. All engines, regardless of type of crankcase cover, should be checked for the tightness of the clamping action on the outer race of the thrust bearing at each overhaul as follows:

Clean the machined surfaces of the front crankcase and front crankcase cover. Then install the thrust bearing, making sure it is driven all the way back against the shoulder of the cover.

Measure the distance from the front face of the front crankcase section to the front face of the outer thrust bearing race.
. . . . . .Dimension "B" in **150** using a depth micrometer. . . **151** and **152**

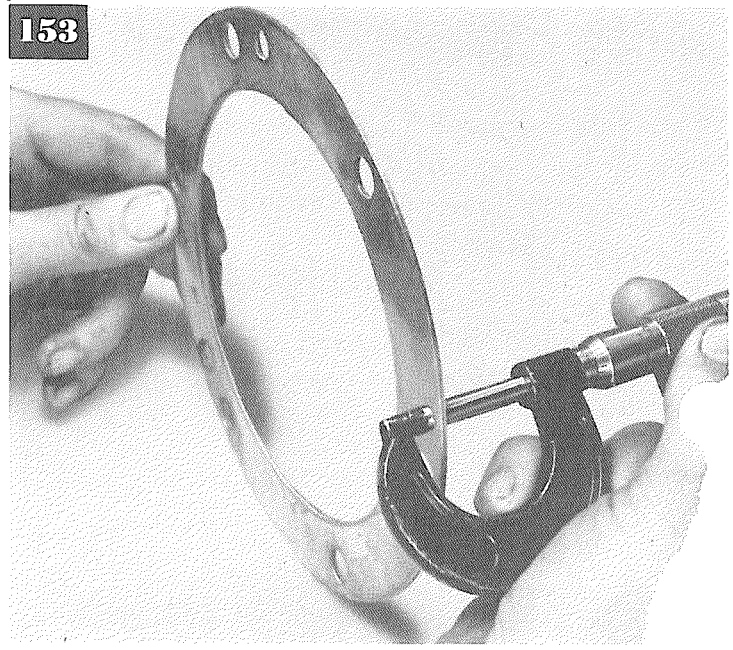
Measure the distance from the parting surface of the front crankcase cover to the edge of the shoulder bearing against the thrust bearing outer race.
. . . . . .Dimension "A" in **150**

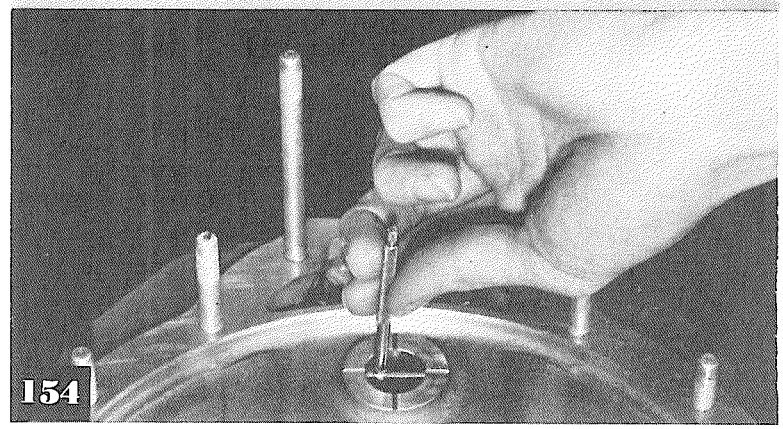
On engines equipped with the old type cover subtract dimension "B" from dimension "A" which is the clamp fit of the front crankcase cover.

On engines equipped with the new type cover, make the same measurements and subtract dimension "B" from dimension "A". From the result subtract the thickness of the shim "C." **150**

This figure should be within the limits stated in the Table of Limits, Chapter IX of this Handbook. If less than the specified minimum, one or more laminations must be peeled from the shim to obtain the proper clamp fit on the thrust bearing. **153**

153





Main Crankcase

Examine the upper and lower halves of the main crankcase for nicks, dents, scratches, cracks or other signs of damage paying particular attention to the parting surfaces, supporting webs, and the stud and bolt holes. Make sure that all the oil passages are cleaned of obstructions. Inspect all dowels for tightness of fit and for condition. Examine the interior and end faces of all bearing bosses for signs of scoring or excessive wear. Using an inside micrometer, measure the diameter of all the bearing bosses. **154**

Examine all studs for condition of threads and tightness; also examine for stretch by measuring the length of the protruding section using a depth gage. **155**

Inspect the four engine mount brackets for nicks and cracks and for condition of holes for attaching studs. Examine the engine mount bushings for condition.

Examine the accessory drive shaft for cracks, condition of journals, threads, splines and keyway and for alignment. Measure the outside diameter of all the journals and check the diameter against the inside diameters of the corresponding bearings in the crankcase upper to determine clearance. Examine all oil passages to make sure they are clear of obstructions; also examine the oil transfer tubes for condition.

Inspect the accessory drive shaft gears for indications of improper mesh, excessive wear, burrs, pits and cracks. Examine the front gear for condition of keyway and the rear gear for condition of internal splines.

Examine the main bearings for signs of scoring or overheating and for cracks.

Replace all unserviceable main bearings and then install the bearings in their proper locations in the upper and lower crankcase. Assemble the two halves of the case. Install the 14 main bearing stud nuts and tighten to the proper torque. Using an inside micrometer, measure the diameter of all main bearings in a vertical plane. **156**

The bearing halves have chamfered edges at the parting surfaces which will interfere with the correct measurement of the bearing diameter if it is checked too near the parting surface. Therefore, when checking the horizontal bearing diameter, the micrometer should be held at about 15° to the parting surface, first in one direction and then in the other.

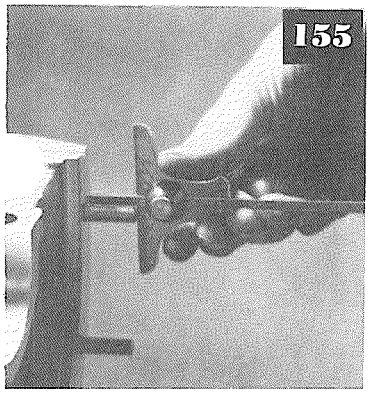
Do not separate the crankcase halves before checking the alignment of the vertical drive shaft gears.

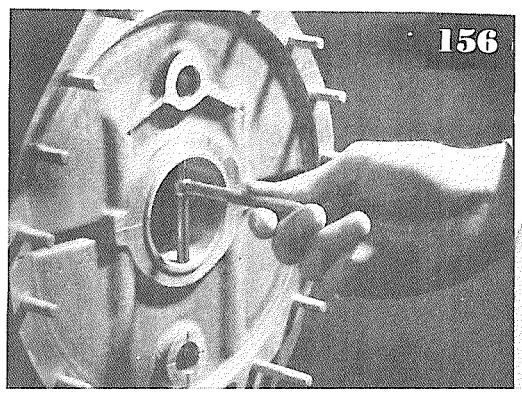
Inspect the breather body and covers for signs of cracks, nicks, dents or other damage. Examine the screw holes in the body for signs of mutilation to the threads. The screen in the outer cover should be checked for cleanliness, condition, and to see that it is securely staked in the cover. Make sure that all oil drain holes are free of obstructions.

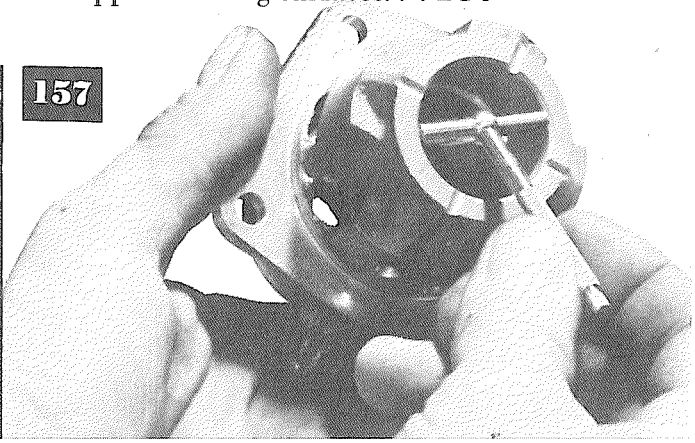
Vertical Drive

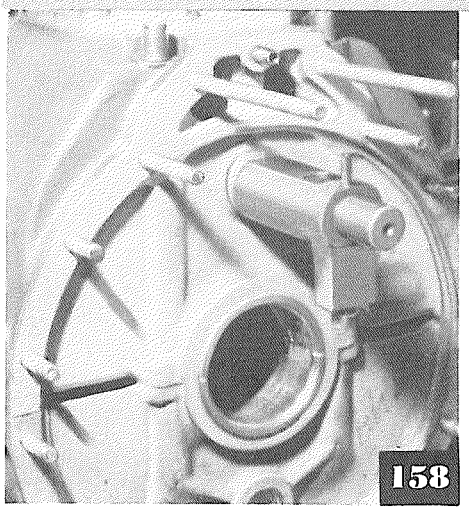
Examine upper and lower vertical drive supports for nicks, dents and scratches or cracks. Check condition of parting surfaces, stud holes, bearing surfaces, and threads.

Measure the inside diameter of the upper and lower support bearing surfaces. . . **157**





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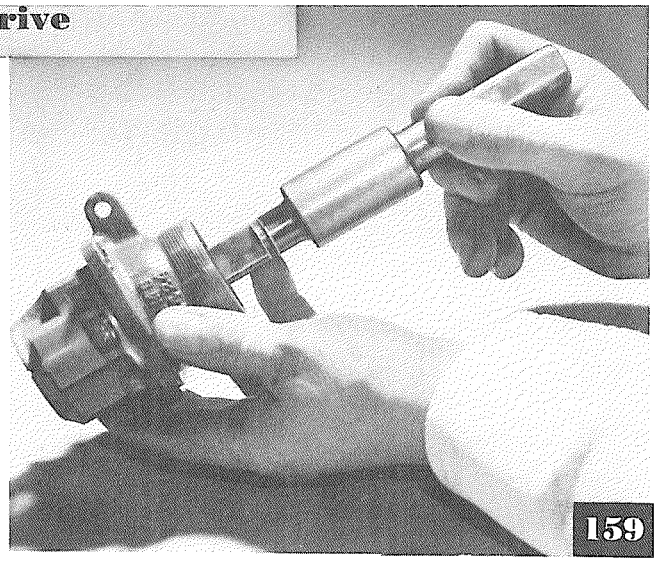
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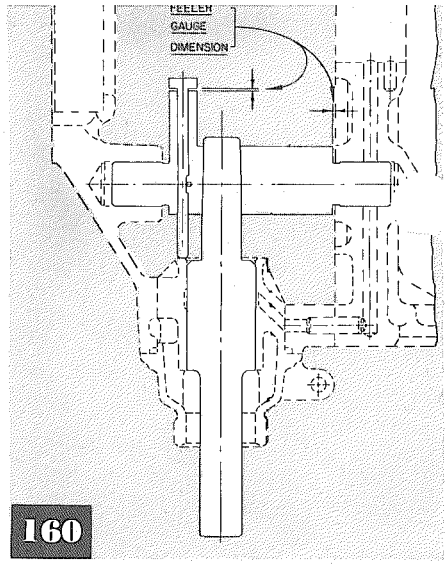

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Examine the vertical drive shaft housing for dents, nicks or cracks and for condition of plating.

Inspect the packing nuts for cracks, dents, distortion and condition of thread and castellations.

Examine the upper and lower vertical drive gears for indications of improper mesh, excessive wear, burrs, pits or cracks, and for condition of internal splines. Measure the outside diameter of the gear journals, also inspect the journals for condition and wear.

Inspect the vertical drive shaft for cracks and for condition of journals, threads, splines and for alignment.

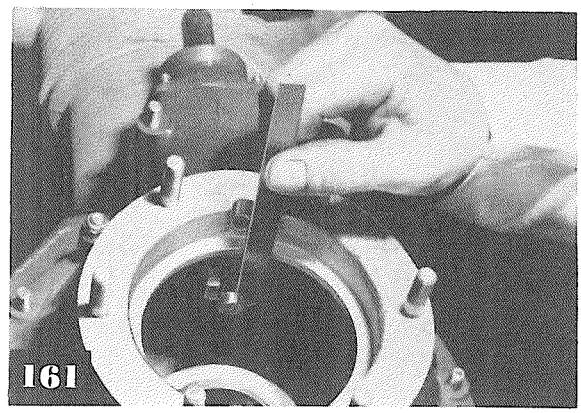
Examine the thrust washers for roughness, nicks, cracks or bends.

Proper alignment of the vertical drive shaft bevel gears with the lower front idler bevel gear and the camshaft front bevel gear is obtained by installing spacing washers of the correct thickness behind each gear.

Check alignment of the vertical drive shaft upper gear and the lower front idler gear to determine the proper thickness of spacing washers as follows:

Attach vertical drive shaft housing upper support to the front crankcase using two nuts and washers. Install Gage No. 1 supplied with Upper Vertical Drive Gear Alignment Fixture, AT-212, in place of the lower front idler gear assembly, with the flat side toward the vertical drive shaft housing upper support. **158**

Attach the front crankcase to the main crankcase with two nuts and washers on opposite sides of the front crankcase.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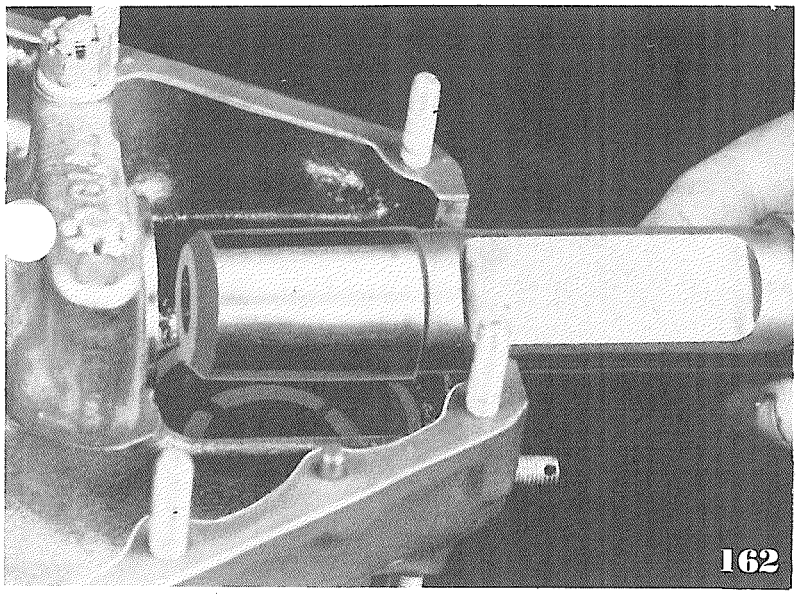
Insert Gage No. 2 supplied with AT-212 in the vertical drive shaft housing upper support and push it solidly into Gage No. 1 with the flat sides of Gage No. 2 parallel to the axis of Gage No. 1. . . . . **159**

Using a feeler gage, obtain the dimension from the shoulder of Gage No. 1 to the thrust face of the boss in the lower crankcase, Dimension "A". **160**

Add .735 inches to the feeler gage dimension and subtract the thickness of the lower front idler spur gear hub, which is etched on the hub, Dimension "B". **160**

If the etch marks indicating the hub thickness have been obliterated in service, the lower front idler bevel and spur gears must be disassembled and the thickness of the spur gear hub measured with a micrometer.

Hold Gage No. 3 supplied with AT-212 firmly against the thrust face of the vertical drive shaft housing upper support and use a feeler gage to obtain the dimension between the head of Gage No. 3 and Gage No. 1. Dimension "C". . . . . **160** and **161**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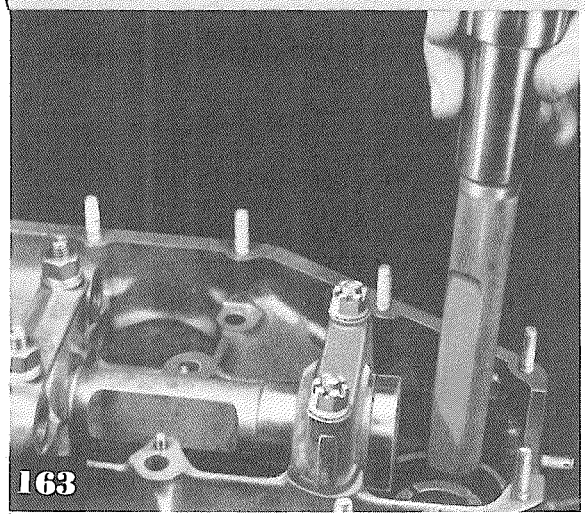
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Subtract the gage dimension from .080 inch.

Check alignment of the vertical drive shaft lower gear and camshaft front gear to determine thickness of spacing washers as follows:

Attach the vertical drive shaft lower support to the camshaft housing, making sure that the oil transfer dowel lines up with the dowel hole, and secure with all four attaching nuts. Install the front camshaft bushing and front bearing cap, making sure that the shoulder on the bushing fits snugly back against the bearing cap. Install No. 6 camshaft bearing cap in its correct location.

Insert Gage No. 1 supplied with Lower Vertical Drive Gear Alignment Gage, AT-382, horizontally through the front camshaft bushing and front camshaft bearings. **162**

Insert Gage No. 2 supplied with AT-382 vertically through the bore of the lower vertical drive shaft support. **163**

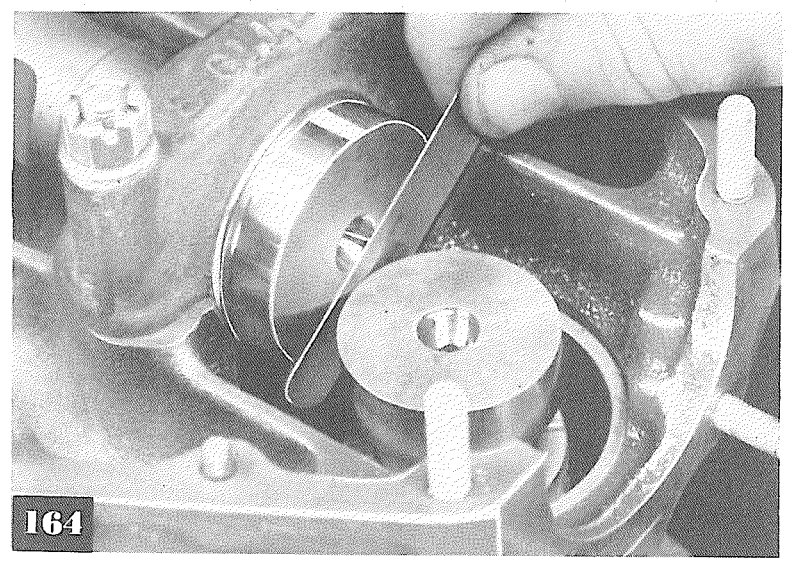
Press the horizontal gage (No. 1) all the way back against the shoulder of the camshaft front bushing and raise the vertical gage (No. 2) so that its upper end is opposite the center line of the horizontal gage. Measure the clearance between the two plug gages with a feeler gage. **164**

Add .050 inch to the reading obtained. The result is the proper thickness of the thrust washer to use behind the camshaft front gear.

Press the vertical plug gage (No. 2) hard against the vertical shaft lower support and pull out the horizontal plug gage (No. 1) so that its forward end is approximately over the center line of the vertical gage.

Measure the clearance between the two plug gages with a feeler gage. **165**

Add .050 inch to the reading obtained. The result is the proper thickness of the thrust washer to use behind the vertical drive shaft lower gear.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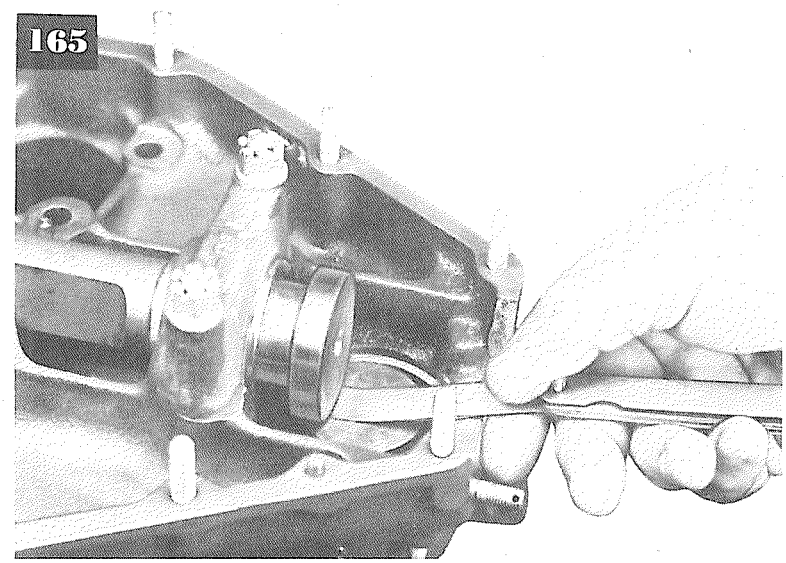
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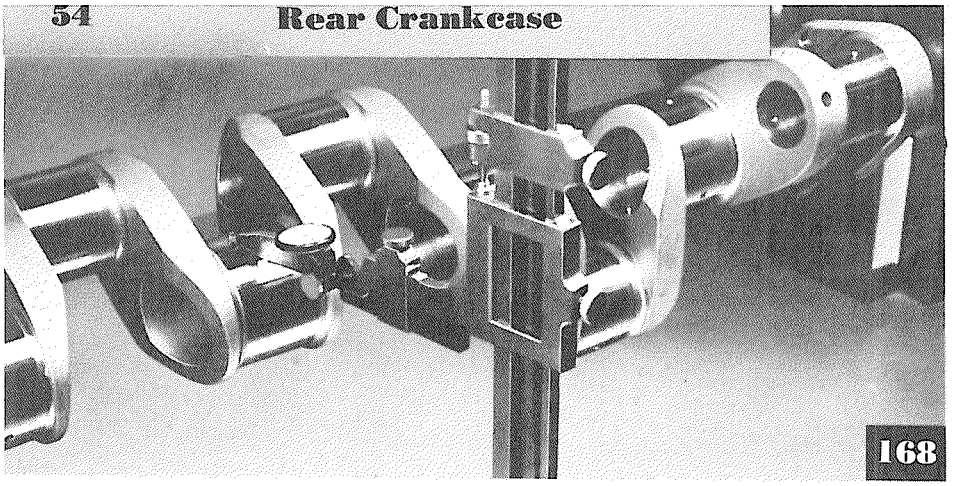

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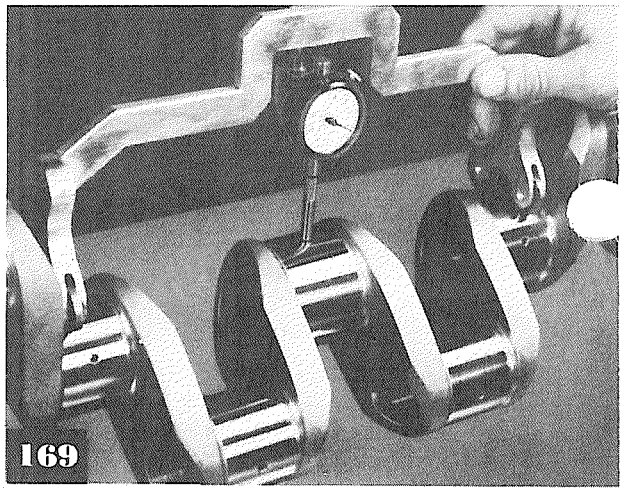

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Rear Crankcase

Inspect the rear crankcase section for nicks, dents, cracks or other signs of damage paying special attention to the flanges and parting surfaces, and to the stud and bolt holes. Make sure that all oil passages are clear and all threads are in good condition.

Examine all dowel pins for condition and tightness. Inspect all studs for condition of threads and tightness; also for stretch.

Examine the interior and end faces of all bearing bosses for signs of scoring or excessive wear. Measure the inside diameter of all the bearing bosses.

Examine the generator adapter for nicks, dents or cracks and for condition of stud holes and parting surfaces. Check condition and measure the inside diameter of the bearing.

Inspect the pressure oil strainer for cleanliness and condition of mesh; also for dents, cracks, rounded corners or other damage. Examine the pressure oil strainer cover for cracks and condition of threads.

Examine the pressure oil inlet strainer for dents, cracks, rounded corners and condition of threads; also inspect for cleanliness and condition of mesh. Inspect the oil strainer magnets for nicks, cracks, condition of threads and strength of magnets.

Examine the two rear idler gears, the magneto and vacuum pump drive gear, and the right magneto drive gear for indications of improper mesh, excessive wear, burrs, pits, cracks, and for condition of threads and keyways. Measure the outside diameter of all the gear journals, and check against the inside diameter of the corresponding bushings to determine clearance.

Check the vacuum pump and tachometer drive housing and cover for cracks, nicks, dents or other signs of damage, especially at the parting surfaces and at the oil retainer seat. Examine all studs for tightness and for condition of threads. The tachometer·gear adapter should be examined for general condition and for tightness of fit in the housing. The gears should be checked for condition of teeth and for signs of damage to the shafts and inserts.

All steel parts that have passed the visual inspection must now be given a magnaflux inspection.

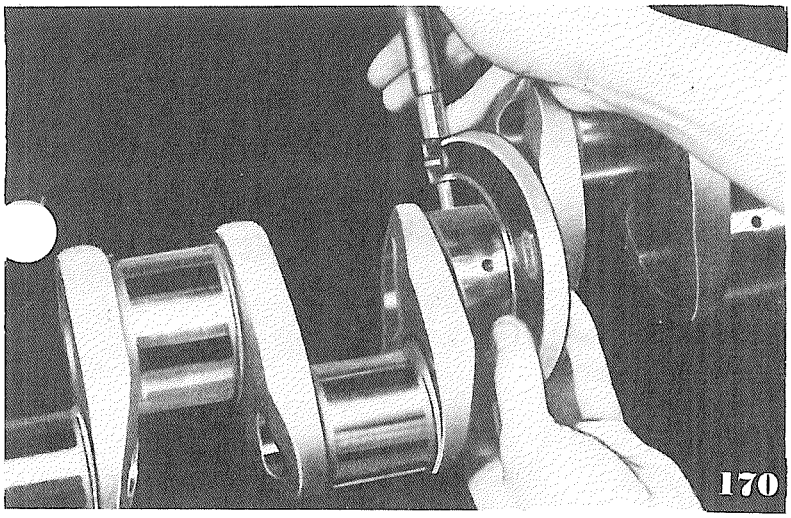
Crankshaft Assembly

Magnaflux all steel parts as outlined in the beginning of this chapter. In addition to magnaflux inspection, the crankshaft should be given a visual inspection to determine the condition of the journals, threads, splines, and keyways with regards to indications of excessive wear, burrs, pits, cracks or scratches.

The crankshaft should also be checked for alignment in the following manner.

Support the crankshaft in two Crankshaft Alignment Rollers, AT-293, or if the rollers are unavailable on vee blocks, resting on a surface plate. The rollers or vee blocks should be placed under the No. 1 and No. 7 main bearing journals. Check the run-out of each main bearing journal with a dial indicator supported on a stand resting on the surface plate, making sure to rotate the crankshaft through two or three revolutions for each main bearing journal measurement. **168**

In addition to checking the run-out of the main journals with respect to No. 1 and No.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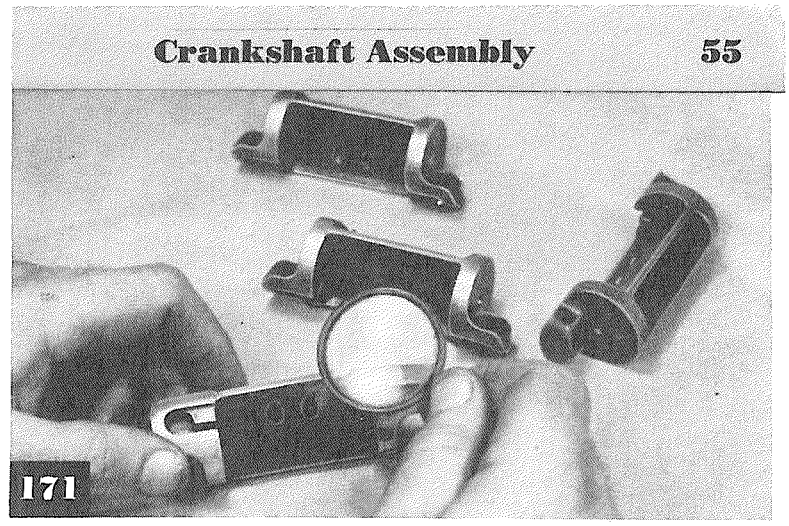
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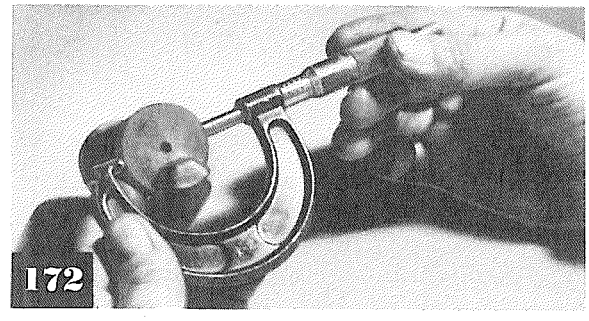
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7 main journals, the run-out of each journal must be checked in relation to both adjacent main journals. To do this, place Fixture, AT-405, equipped with a standard type dial indicator, with the rollers on No. 1 and No. 3 journals and the finger of the dial indicator resting on No. 2 main journal. . . . . **169** Rotate the crankshaft through at least one revolution and record the reading. Repeat this operation for all other main journals. Check all run-out readings against the values given in the Table of Limits.

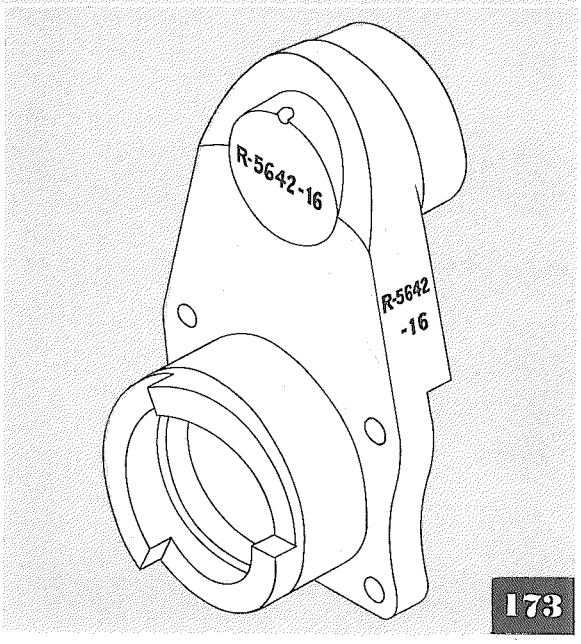
Check the diameter of all main bearing journals and crankpins by making several measurements on each journal and crankpin with an outside micrometer. . . . . **170** Record the readings on the Inspection Form and check against the values given in the Table of Limits. If the diameter of any one journal or crankpin falls below the minimum diameter permissible or if the particular journal or crankpin is scored deeply, it may be ground to a standard undersize. It is not necessary to grind all crankpins or journals on the crankshaft undersize if only a few are defective. However, wherever a journal or crankpin has been ground undersize, this should be indicated by an etched mark adjacent to the undersize journal or crankpin to draw attention to the fact that undersize bearings are required. As a sharp change in cross-section will cause a local stress concentration, the reground surface will have to be blended smoothly into the fillets at the ends of each journal or crankpin. After this, it is necessary to again shot-blast the fillets. As this operation can be performed only at the factory, it is recommended that all crankshafts requiring regrinding be returned to the manufacturer.

Examine the starter drive jaw for condition giving special attention to the teeth with regards to signs of excessive wear, burrs, pits or cracks; also check the jaw for tightness in the shaft.

Examine the starter drive oil slinger for tightness, condition and for signs of interference with the rear crankcase.

Magnaflux all the crankshaft damper parts with the exception of the nuts, bolts and needle bearings which are discarded at every overhaul. In addition, examine the crankshaft damper plate and all the damper weights and rings for nicks, dents, scratches and cracks; also check the damper plate and the attaching pad on the crankshaft for indications of loose contact. Inspect the bolt holes in the damper plate and in the attaching pad on the crankshaft for signs of galling or other indications of damage.

Examine the large and small crankshaft plugs for signs of damage paying particular attention to the edges where a nick, dent or scratch could cause oil leakage. Measure the outside diameter of all the plugs . . . . . **171** and **172** and check against the inside diameter of their respective journals in the crankshaft to determine fit.



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Inspect all the crankshaft plug hollow dowels for signs of mutilation, cleanliness and for proper length.

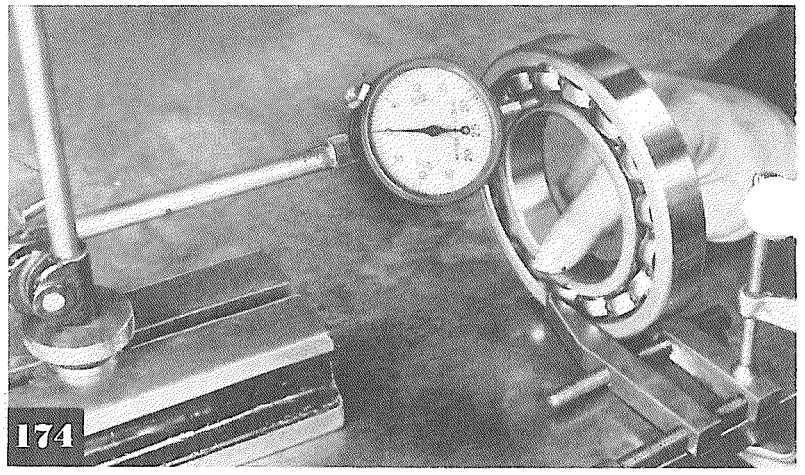
The determining of the correct weight of the crankshaft balancing plug is part of the crankshaft balancing procedure. The weight of these plugs varies with different crankshafts and for this reason they are not interchangeable. The weight of the plug is stamped on both the plugs and the crankshaft. Examine this plug for condition and for proper fit in the No. 1 crankpin journal. Check whether the weight stamped on the rear end of the plug agrees with the weight stamped on the crankshaft. **173**

Examine the crankshaft gear for signs of improper mesh, excessive wear, burrs, pits, cracks, scratches, and for indication of damage to the keyway. Check the crankshaft gear spacer for condition and for fit against the gear.

Check the thrust bearing for freedom and smoothness of rotation and examine the balls and races for pit marks. Inspect the retainer rivets for tightness. The thrust bearings should be checked for end play and wear as follows:

Using two clamps, clamp the outer race of the bearing rigidly to a surface plate.

Set up a dial indicator support with the indicator in a horizontal position so that the end of the spring plunger bears against a side face of the inner bearing race.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Test the bearing for excessive end play by tilting the inner race with reference to the outer race and noting the maximum movement on the dial indicator. **174**

Refer to the Table of Limits for maximum permissible tilt between inner and outer bearing races.

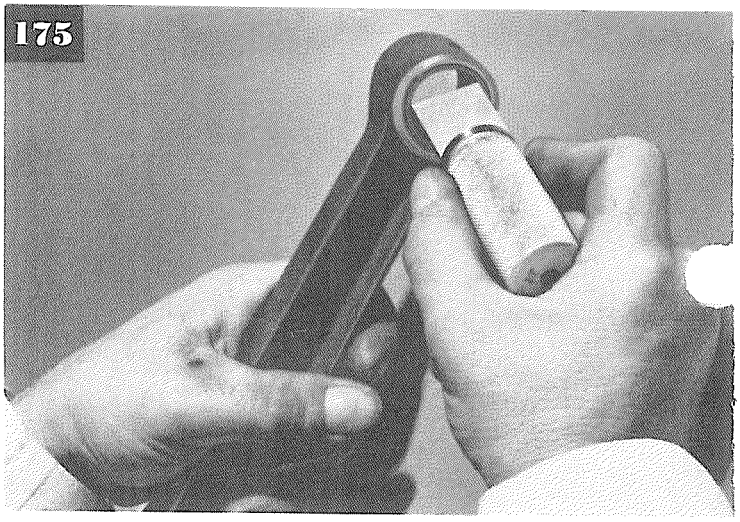
Examine the crankshaft oil slinger for nicks, cracks, distortion or wear due to interference with the front crankcase cover. The thrust bearing nut should be examined for cracks, dents, distortion and for the condition of the threads and castellations.

Connecting Rods

All the connecting rods are inspected visually and by the magnaflux method. Examine all the rods and caps for nicks, dents, scratches, cracks or other signs of damage. Check all the connecting rod bolts for signs of stretch or mutilation, and the nuts for condition of thread and castellations.

Check the inside diameter of all the Connecting Rod Bushings using Gage, AT-292. . . . . **175**

Also check the bushings to make sure they make a tight fit in the small end of the connecting rods and that they are securely pinned in.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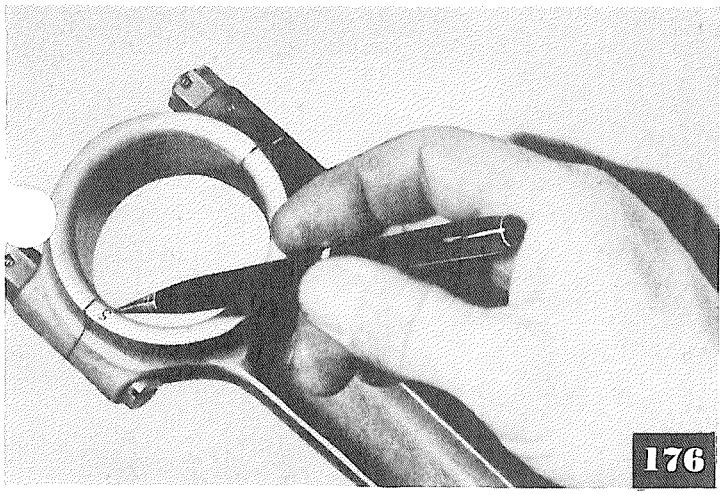
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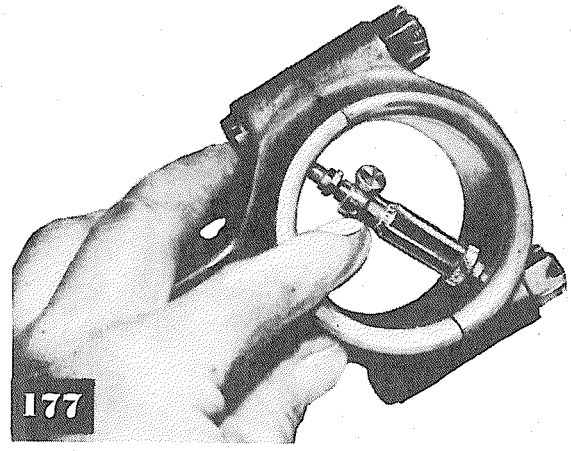
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Examine all bearings visually for scratches or cracks, especially around the oil holes. Check for loosening of the bond between the bearing metal and the backing; also examine the bearing surfaces for inclusions of foreign particles. Check the oil holes to see that they are free of obstructions.

Connecting rod bearings which have been previously installed have their location number stamped on them. **176**

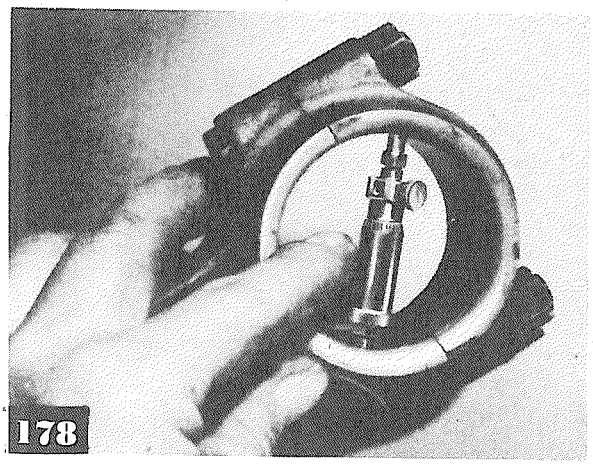
New bearings should be similarly marked as soon as they are installed in a connecting rod.

Assemble the connecting rods with their respective bearings and measure the bearing diameter with an inside micrometer. The diameter must be measured at right angles to the bearing parting surface. . . **177**

The diameter should also be checked about 15° on either side of the parting surface. **178**

The connecting rod bearing diameter is slightly larger at the edges of the bearings than at the center. Therefore, all measurements should be taken at the center of the bearing.

The connecting rods should be checked for bend and twist as follows: Place the connecting rod assembly in its proper position on the Connecting Rod Alignment Fixture, AT-385. Locate the toggle on the side of the fixture in the up position. Apply pressure down on the top of the bushing end of the connecting rod, making sure the bearing end of the rod is pressing against the locating pin of the fixture. The amount of bend will now be shown on the indicator. **179**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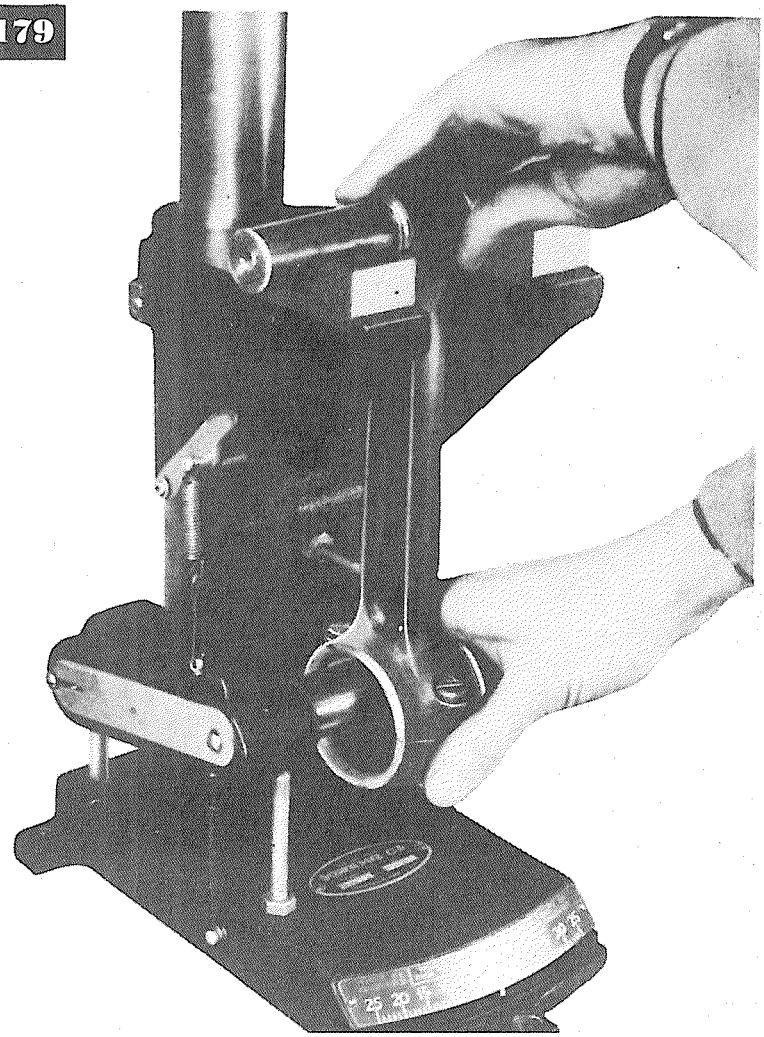
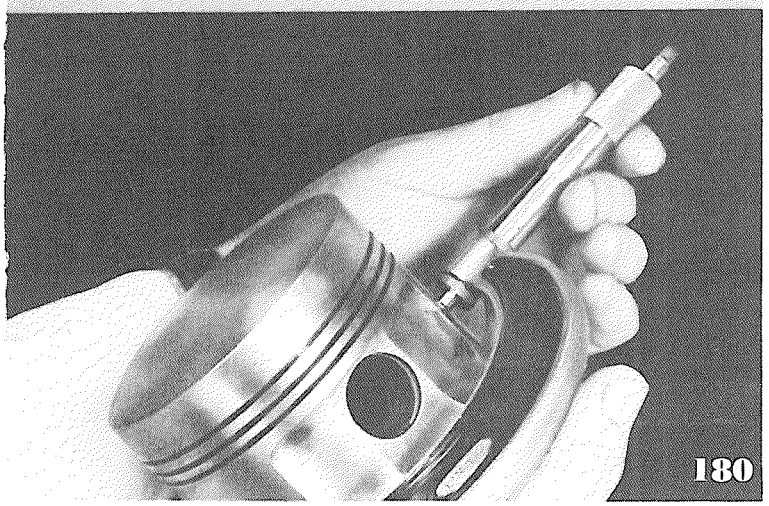


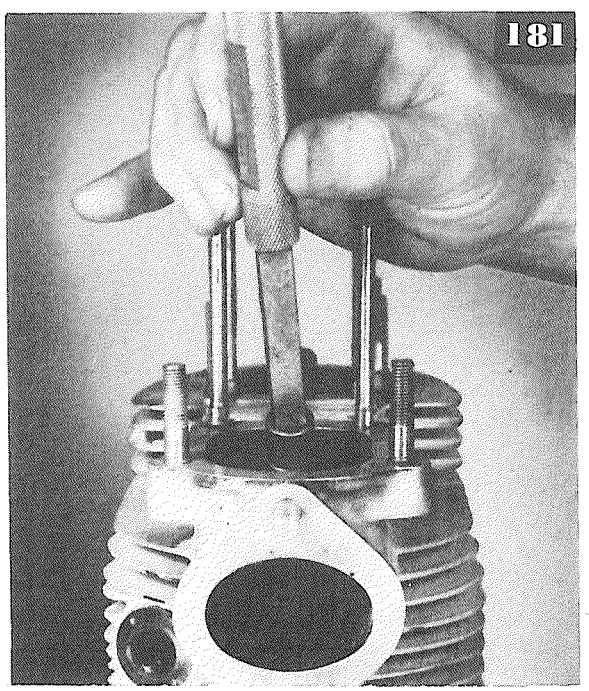


To determine the amount of twist, change the toggle to the down position. Press down on the bushing end of the rod and, using a slight pressure, keep the bearing end of the rod away from the locating pin on the fixture. The indicator will now show the degree of twist in the rod.

Cylinders and Pistons

Inspect all pistons for cracks around the piston pin boss and in the piston ring grooves. Check the piston skirt for scoring, and the piston head for mutilation by foreign particles which may have entered the combustion chamber while the engine was running.

Check the diameter of the piston at the top and bottom of the skirt with a micrometer. **180**
Since the pistons are cam ground, it is important to check the diameter at exactly right angles to the piston pin. The piston



diameter should be checked against the diameter of the cylinder in which they are to be installed and the clearance obtained in this way should be checked against the maximum permissible value given in the Table of Limits. The oil holes drilled in the scraper ring groove should be inspected to be sure they are completely free of any obstruction. The circlip grooves should be examined for burring or nicks.

All piston pins should be given a magnaflux inspection. In addition, they should be given a visual inspection for signs of excessive wear, dents, scoring or corrosion. The piston pin's diameter should be measured with a micrometer at both ends of the pin and in two planes at right angles to each other, to determine whether the pin is worn or out of round.

Inspection of piston rings is not discussed as it is recommended that the rings be replaced at each overhaul.

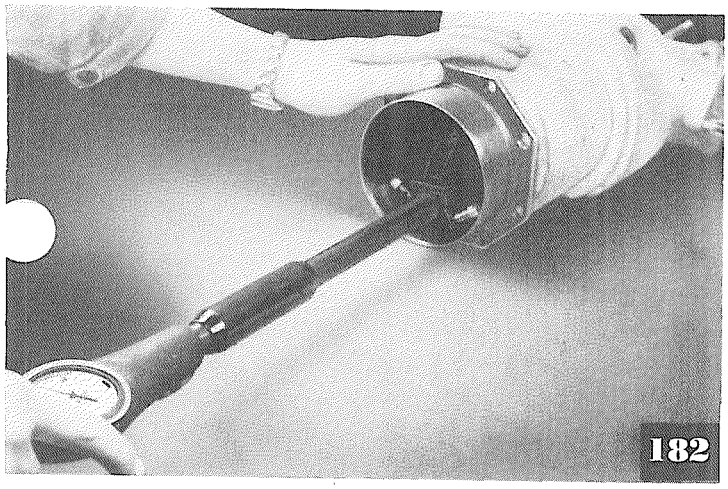
Examine the cylinder heads for nicks, cracks, broken fins and loose or broken studs.

Examine the intake and exhaust valve guides for scoring, signs of overheating and tight fit in cylinder head. Check the inside diameter of the intake valve guide with Gage, AT-217. . . . . **181**
If the gage enters in any position, the guide must be replaced. Check the inside diameter of the exhaust valve guide in same way, using Gage, AT-218. Examine the intake and exhaust valve seats for condition, and for tight fit in cylinder head; also examine the area of valve face contact.

Examine the spark plug inserts for condition of the threads and tightness in cylinder head.

Examine the cylinder barrel for scoring or other signs of overheating; also inspect for scratches, cracks, bent or broken fins and other damage. See that the barrel fits tightly in the head. Examine condition of the cylinder skirt, the hold-down flange, and the stud holes.

Using a cylinder gage, check the bore of the cylinder at the top, center and bottom of the barrel to determine whether it is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tapered. Check the diameter in the fore and aft plane and at right angles to it to determine whether the cylinder is out of round. 182

All valves, valve springs, valve spring washers and washer locks should be magnafluxed. In addition, they should be visually inspected as follows:

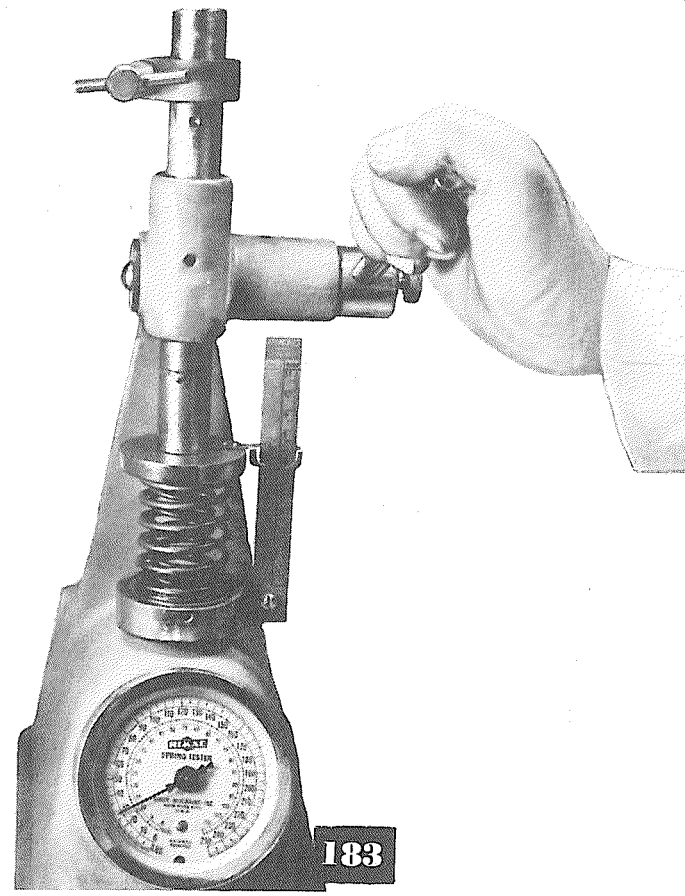
All intake or exhaust valves should be examined for signs of burning, pitting, scaling, feathering or warping. Slight dishing of the intake valve contact surface is permissible. Valves in this condition need not be refaced unless the contact surface is pitted or ridged. The valve stems should be checked for indications of scoring or excessive wear, and for alignment.

Valve springs, valve spring washers and washer locks should be examined for nicks, dents, scratches, cracks and warping. In addition, the valve spring's tension should be checked using Valve Spring Compression Gage, AT-291. 183

Inspect the exhaust port adapters for indications of burning, also for nicks, dents, scratches and cracks, giving special attention to the faces and bolt holes.

Camshaft Housing

Inspect the camshaft housing and cover for mutilation and for cracks. Inspect all machined surfaces for nicks, scratches, and other signs of damage. Examine the camshaft housing for corrosion, especially around the forward cylinder attaching pads and around the cylinder head baffle screw holes. Inspect all the studs for looseness and condition of thread. Check especially the lengths of the studs which hold the camshaft housing cover to the housings, as these studs pull out easily when overtightened. Check the oil transfer dowel at the front end of the housing for tightness and condition.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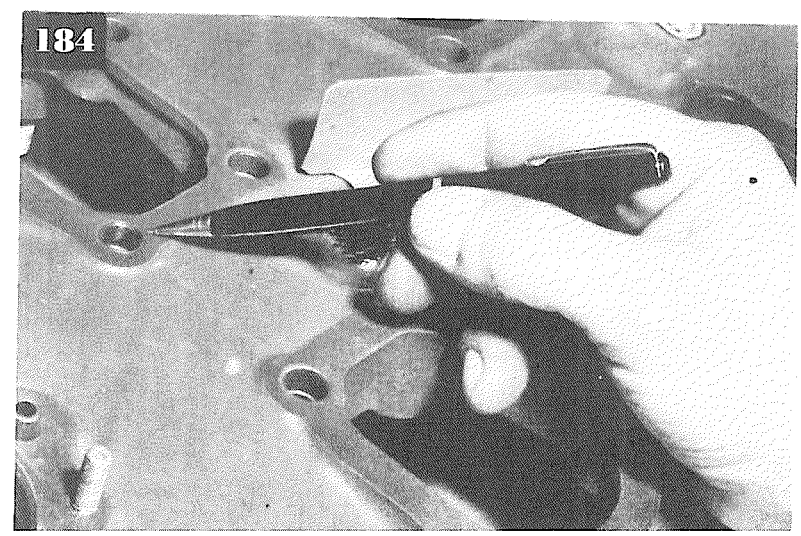
Examine the screw inserts for condition of thread and tightness in the casting. Check the cylinder head baffles for cracks or other damage. Examine the rear oil drain hose connection for condition and for tight fit in the housing. The scavenge oil pipe located in the cover should be examined for evidence of interference with the camshaft flywheel, cleanliness and security of attachment. Check the camshaft housing locating bushings for tightness and condition. . 184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Inspect the camshaft bearing caps for nicks, scratches, cracks and for signs of crushing under the hold-down nuts and washers. Place the caps in their proper position in the camshaft housing and tighten them to the proper torque. Measure the inside diameter of each bearing. Compare each of these diameters against the outside diameter of its respective camshaft journal for clearances.

Examine the front camshaft bushing for condition and for tight fit in the bearing cap. Measure the inside diameter at two locations at right angles to each other.

Check the ball in the end of each rocker arm adjusting screw for tightness in its socket. Pay particular attention to the edge which secures this ball to detect any cracks which might later allow the ball to fall out. Turn the locknut on each adjusting screw the entire length of the thread to check the condition of the thread. Examine all the rocker arm shafts for signs of wear, especially at the areas which come in contact with the rocker arm bushing or bearing. Also check the fit of the rocker arm shafts in the supporting brackets against the values in the Table of Limits. Check the threads for the adjusting screw in the rocker arm for condition. In addition, the rocker assembly should be checked for the fit of the roller on the spacer and the roller rivet for tightness. The rocker roller should be examined for scuffing and the outside diameter checked for roundness.

In addition to checking the diameter of each camshaft journal, check the condition of each journal, especially where the bearing for the particular journal shows roughness or scoring. Examine the cam lobes for wear or scuffing. Check the diameter of the front camshaft journal against the inside diameter of the front camshaft bushing to determine clearance.

Check the splines and threads at the front end of each camshaft for wear, nicks or scratches. Examine the scavenge pump adapters for general condition and for signs of wear in the splines. Check the camshaft damper inner retainer for wear caused by the damper weights. Examine the camshaft damper outer retainer for looseness. Carefully inspect the camshaft damper flywheel, especially at the sharp corners of the damper weight tracks. Inspect the camshaft gear for pitting of the teeth and for wear of the inside spline.

All steel parts which have passed visual inspection, should be magnafluxed as outlined in the beginning of this chapter.

Pressure Oil Pump

Magnaflux all steel parts as outlined in the beginning of this section. In addition to the magnaflux inspection, all parts should be given the following visual inspection.

Examine the pressure oil pump housing and cover for nicks, dents, scratches or cracks, especially at the parting surfaces and at the stud and dowel holes. Check the locating bushing for the drive shaft for condition and for tightness in housing.

Inspect the gears and shafts for cracks, nicks, dents or other signs of damage. Also check the splines and the gear teeth for indications of wear, burrs, pits, cracks or scratches.

Examine the valve assembly for condition of threads, length, condition and tension of the spring, and for any damage of the valve due to improper seating or the inclusion of foreign particles in the lubrication system.

Scavenge Oil Pump

Examine the scavenge oil pump housing and cover for nicks, dents, cracks or other signs of damage, especially at the parting surfaces, the stud and dowel holes and the oil retainer seat. Inspect the fuel pump spacer for the condition of the stud holes, for signs of mutilation, or for softening of the fiber.

Inspect all gears, shafts and adapters for indications of improper mesh, excessive wear, burrs, pits or cracks, especially to the teeth and splines.

Examine the oil inlet strainers for nicks, dents, cracks, rounded corners or other damage. Also check for cleanliness and condition of threads. The scavenge oil magnets should be examined for nicks and cracks,

condition of the threads, and for the strength of the magnets.

All steel parts that have passed visual inspection must now be given a magnaflux inspection.

Induction System

Examine the intake pipes for dents and cracks, and for signs of weakness or splitting around the mounting flange.

Examine the manifolds for cracks, especially through the bolt holes or at the holes which carry the pipe plugs. Inspect the packing nut threads for condition, and the manifolds for corrosion.

It is important to check the alignment of the intake ports. To do this, place the manifold on a surface plate and try to insert a .0015" feeler gage between the surface plate and each intake port. Since the manifold attaching nuts will tend to bend the ears of the manifold towards the cylinder, the most likely place for the feeler gage to enter will be half way between the stud holes. . . **185**

All the packing nuts should be examined for cracks, dents, distortion, condition of threads, and for mutilation of the castellations. Check the thin brass washers which fit under the nut and discard any that are bent or pinched. Check the hot spot for cracks, nicks and loose studs.

Ignition

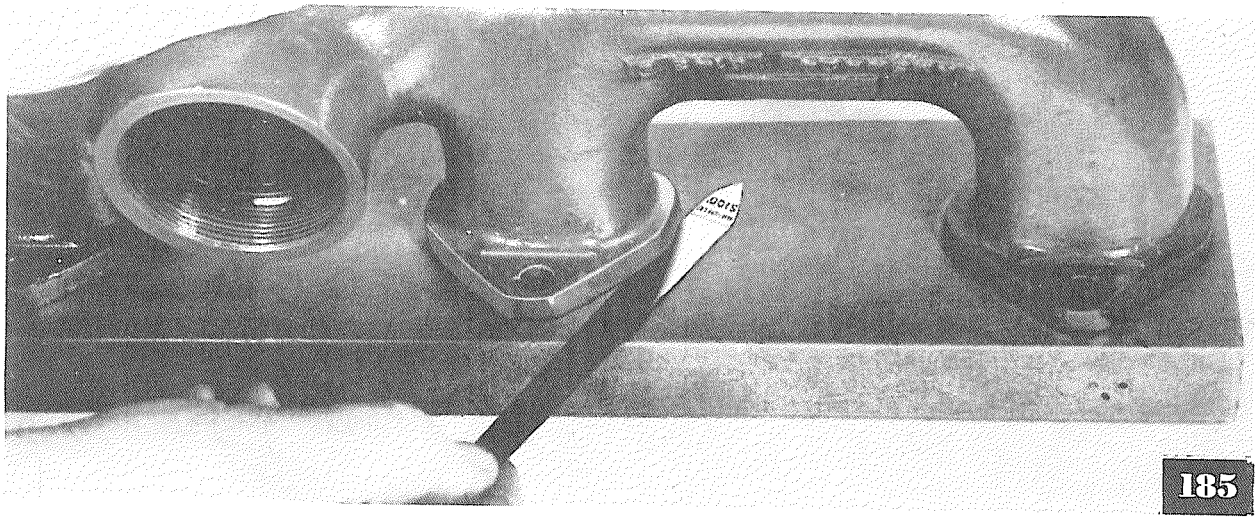
All ignition wires should be replaced at overhaul. The ignition wire manifolds should be examined for cracks, dents, scratches, bends or twists, rough edges, or other signs of damage. Examine the retaining clips for condition, and the rubber grommets for any signs of wear which might cause chafing of the wires against the edges of the manifold inlet or outlet holes. Inspect the magneto terminals for cracks, breaks or excessively burned electrodes. The spark plug terminals should also be checked for indications of wear or damage. If radio shielded harness is used, the contact springs should be replaced at each overhaul.

Examine the two magneto drive couplings and the right magneto driven coupling for nicks, dents, scratches or cracks. Check the condition of the teeth, keyways, and seating surfaces on the shafts. The coupling should also be given a magnaflux inspection as outlined in the beginning of this section.

The rubber magneto intermediate couplings should be replaced at each overhaul.

Baffles

The front and all intermediate baffles should be inspected for nicks, dents, cracks or bends. The rivets attaching the hinges and anchor nuts, should be examined for tightness. The front baffle spring should be examined for condition, tension, and tightness of the rivets securing the anchor nut. All the attaching screws should be checked for straightness, condition of threads and heads, and the clamps should be checked for condition.



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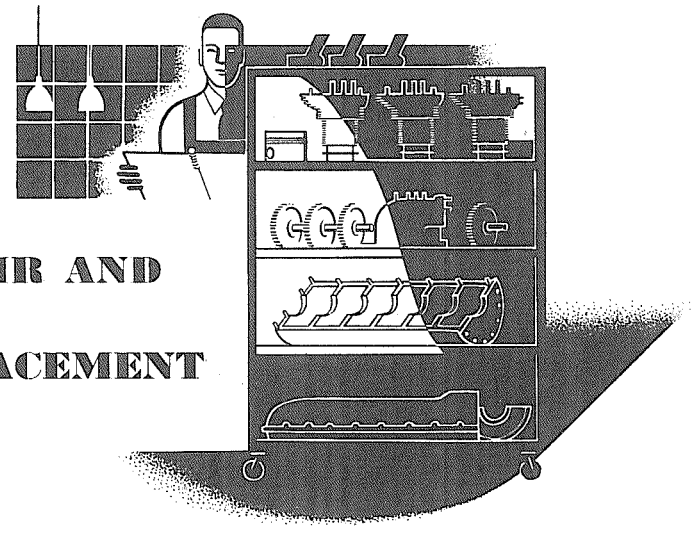
CHAPTER IV



REPAIR AND REPLACEMENT

This section includes all the detailed instructions for the repair and replacement of parts necessary to restore the engine to a satisfactory operating condition. The table of limits of this manual should be used in determining whether parts should be repaired or replaced.

All parts, regardless of whether they are to be repaired or replaced, should be handled with care and protected at all times against dirt and corrosion. All nicks, scratches or other minor injuries that might occur during the repair or replacement of a part, should be completely stoned out before progressing to the next operation. To facilitate the removal and replacement of studs, a Stud Replacement Kit, AT-594, is available. To prevent possible damage to the threads when replacing studs, the use of a thread lubricant is recommended.

FRONT CRANKCASE

Any rework required on the front crankcase should be done in accordance with the instructions outlined in Chapter I. Scratches or galled areas on the parting surfaces may be stoned slightly, provided not enough metal is removed to cause an oil leak.

Loose or defective studs should be replaced at this time and all gears should be repaired in accordance with the instructions outlined in Chapter I.

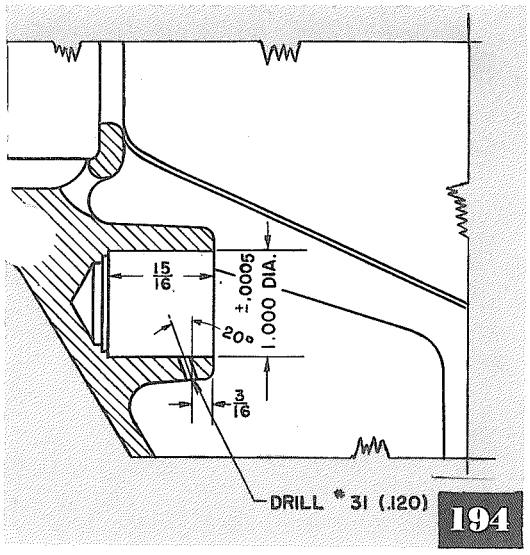
Installation of Replacement Bushings

If inspection has shown any of the bearing boss surfaces in the front crankcase to be damaged, worn oversize, or out of round, the bearing bosses may be rebored to an oversize that permits the installation of bushings. The procedure required to accomplish this rework is as follows:

Attach the Bearing Rework Jig, AT-423, to the rear of the front crankcase.

Information as to the proper size boredrill and specifications necessary for the proper reworking of the bearing boss is contained in the following table.

Bearing Boss	Face off Below Parting Surface	Boredrill Tool No. and Size	Bore to Depth of—	Chamfer Angle Depth
Crankcase Front Section				
Lower Front Idler Gear	Do not face off	AT-445 1.000"	15/16"	Do not chamfer
Upper Front Idler Gear	1.282" ± .002"	AT-426 .937"	15/16"	45° 3/64"



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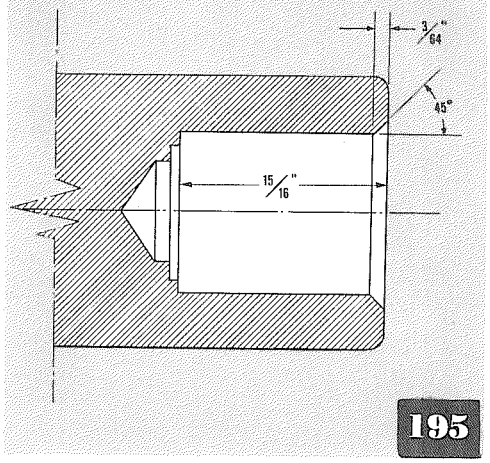

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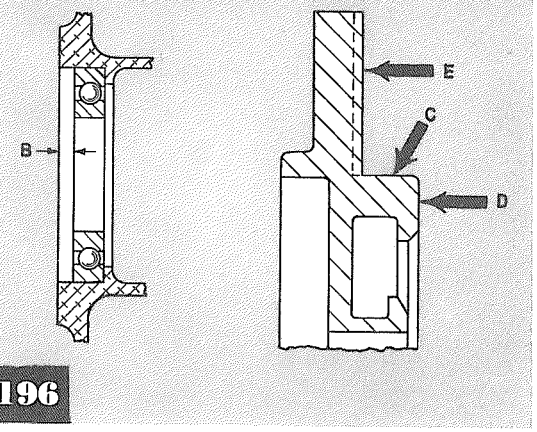

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To install a plain bushing in the lower front idler gear bearing boss, the following rework must be done. Counterbore the bearing boss recess to a depth of 15/16 of an inch, using a long one inch Boredrill, AT-445.

Place the bushing in a bath of denatured alcohol and dry ice for about twenty minutes. After the bushing has been thoroughly chilled, it can be tapped into place with a fiber mallet.

Locate a point for drilling on the under side of the boss, 3/16 of an inch forward of the rear face. Use a No. 31 drill and drill a hole through the boss and bushing at a forward angle of 20 degrees. **194**
Clean up the rough edges of the hole drilled in bushing and drive a brass retaining pin (Part No. 124) into position from the under side of the boss. Secure the pin in position by peening the edge of the hole in the boss over the pin.

The upper front idler gear bearing boss is repaired in the following manner.

Install the Facing Cutter, AT-432, in Holder, AT-444, and chuck the holder in a large vertical drill press. Align the spindle of the drill with the bearing boss to be reworked. Using the fixture as a guide, reface the bearing boss to the depth specified in the table on page 62. Replace the facing cutter and holder by a Boredrill, AT-425, in the drill press. Rebore the bearing boss oversize to 15/16 of an inch deep. The inner edge of the bearing boss must then be chamfered 3/64 of an inch deep at an angle of 45°, using Chamfering Cutter, AT-433. . . . . **195**
Remove the reworking jig from the rear of the front crankcase and press the chilled bushing in place using a composition mallet to tap it in if necessary. Care must be taken to be sure that the oil hole in the bushing lines up exactly with the oil hole in the bearing boss.

Reworking of Front Covers

If inspection has shown that it is necessary to rework an old type front crankcase cover to provide a proper clamping fit on the thrust bearing outer race, the following rework should be done.

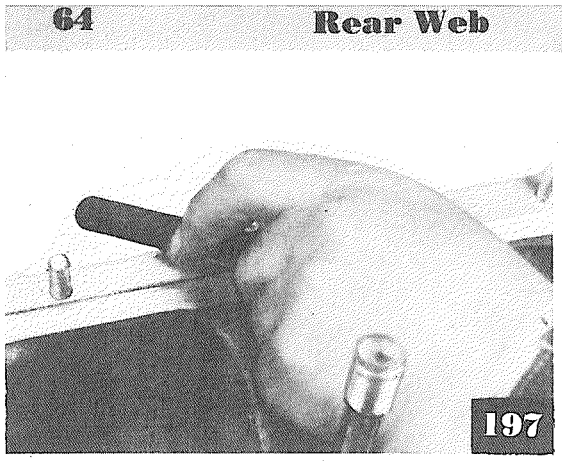
Chuck the cover in a lathe and check for correct centering and alignment with a dial indicator against surfaces (c) and (d) **196**
Cut back the parting surface (e) . . . **196**
so that the dimension (b) **196**
is .319 inch ± .001 in. When reworked in this way, the old type cover is the same as the new type and requires the installation of a front crankcase cover shim.

MAIN CRANKCASE

Should inspection show that either the upper or lower halves of the main crankcase are damaged beyond repair, both halves must be replaced, as they are supplied only in matched assemblies.

All repairs to the accessory drive shaft and the accessory drive shaft gears should be done in accordance with the instructions outlined in Chapter I. Loose or damaged studs should be replaced at this time.

Damaged dowels should be removed with a stud extractor. If the dowel is difficult to remove, the crankcase may be heated to expand the metal around the dowel. The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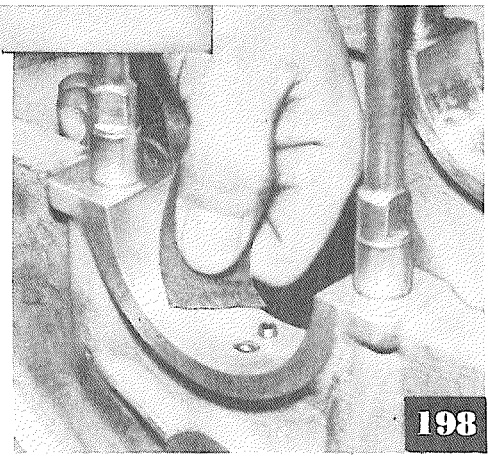
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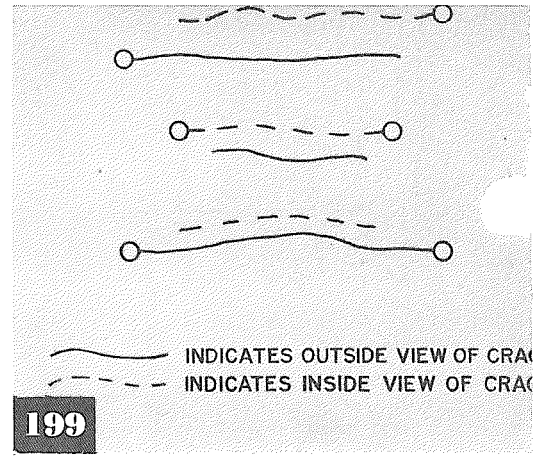

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crankcase should be heated evenly all over, preferably in a hot water bath. Localized heating, such as is accomplished with a blow torch, should never be used as this method may crack the crankcase.

Slight nicks or scratches on the parting surfaces or cylinder pads should be stoned out, ... **197** provided not enough metal is removed to cause an oil leak. Main bearing journals or gear bosses that appear slightly rough but are not worn excessively, may be polished with crocus cloth. **198**

Rework of Rear Web

If a crack has been found in the rear web of the upper crankcase around the accessory drive shaft bushing, the following work should be done:

Thoroughly clean the area adjacent to the crack on both sides of the web in order to be able to locate the ends of the crack. The crack may have progressed further on one side of the web than on the other. **199** Where the crack has progressed less than 180 degrees around the boss, the crankcase can be salvaged as follows:

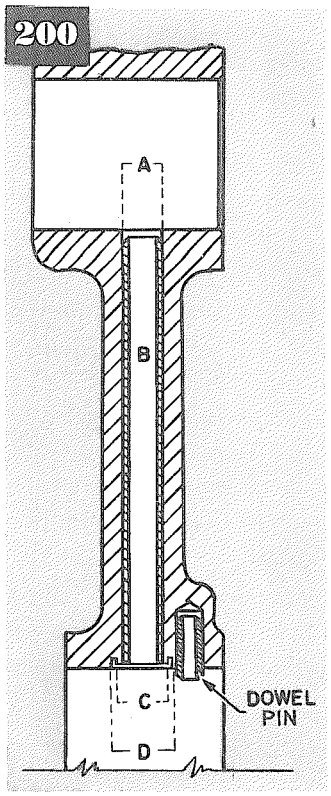
Center punch 1/16 of an inch beyond the furthest ends of the crack, and drill a hole at each of these two points with a 1/8 inch drill. The holes may have to be drilled either from the rear or from the front of the web, depending on which side the crack has progressed further.

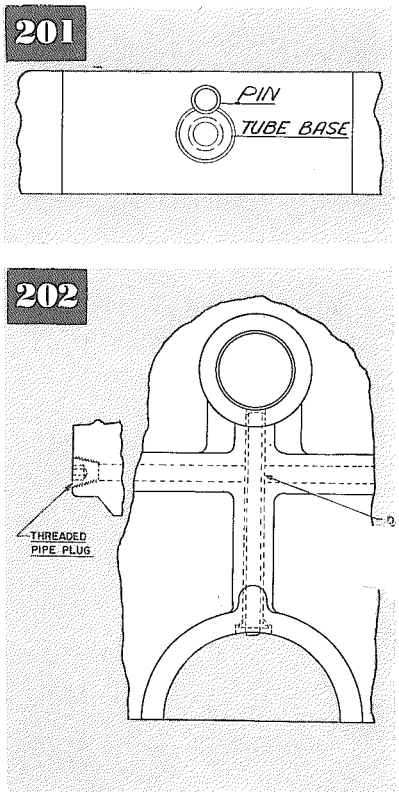
Remove the No. 1 main bearing dowel pin. Drill through the oil passage between the main bearing and the accessory drive shaft bushing, dimension (a), using a 21/64 inch drill, being careful not to hit the opposite side of the accessory drive shaft bearing. Next, counterbore the end of the oil passage at the main bearing, using a 9/16 inch counterbore to a depth of .090 inch ± .010 inch, dimension (d). Then countersink 110 degrees by .390 inch ± .010 inch, dimension (c). Finally finish ream oil passage to .3437 inch ± .005 inch.

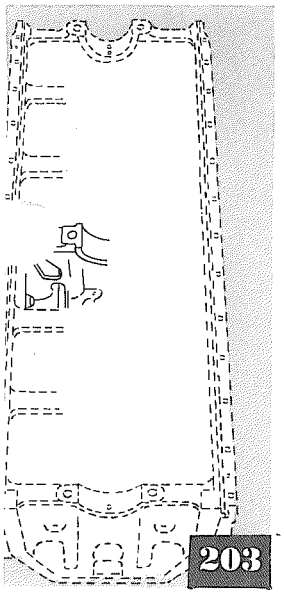
Line up the notch in the flange of the reinforcing tube with the dowel pin hole **200** and press the tube all the way into the oil passage. Check whether the end of the tube will clear the main bearing, then insert pin. **201**

Remove both pipe plugs from the ends of the transverse oil passage in the rear crankcase.

Drill a hole through the tube just installed, demension (b) . . . . . **202** with a long 1/4 inch drill inserted into the transverse oil passage.



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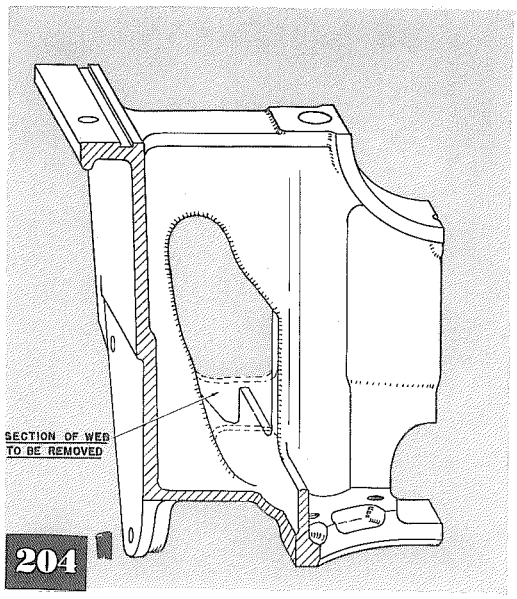

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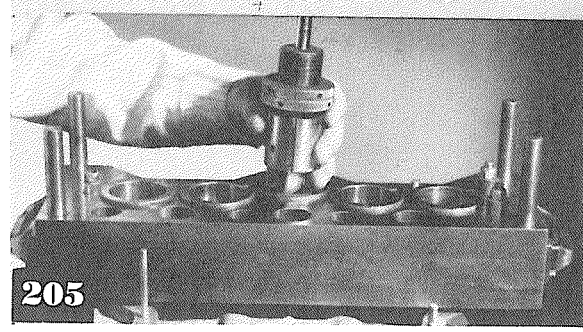
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Clean out all the oil passages thoroughly. Inspect for the proper alignment of the holes and for dirt and obstructions before replacing the pipe plugs.

Rework of Center Web

If a crack has been found in the lower crankcase in the section of the center web between the two openings on the left side (behind the hotspot mounting pad) the following rework operation is recommended:

Cut out the section of the web between the two holes in accordance with .....**203** and **204** using a saw. Round off all edges and blend all radii.

Installation of Replacement Bushings

If inspection has shown any of the bearing boss surfaces in the front or rear webs of the upper or lower main crankcase to be damaged, worn oversize or out of round, the bearing boss may be rebored to an oversize that permits the installation of bushings. The following instructions apply only to the bearing bosses in both the front and rear webs of the upper and lower main crankcase.

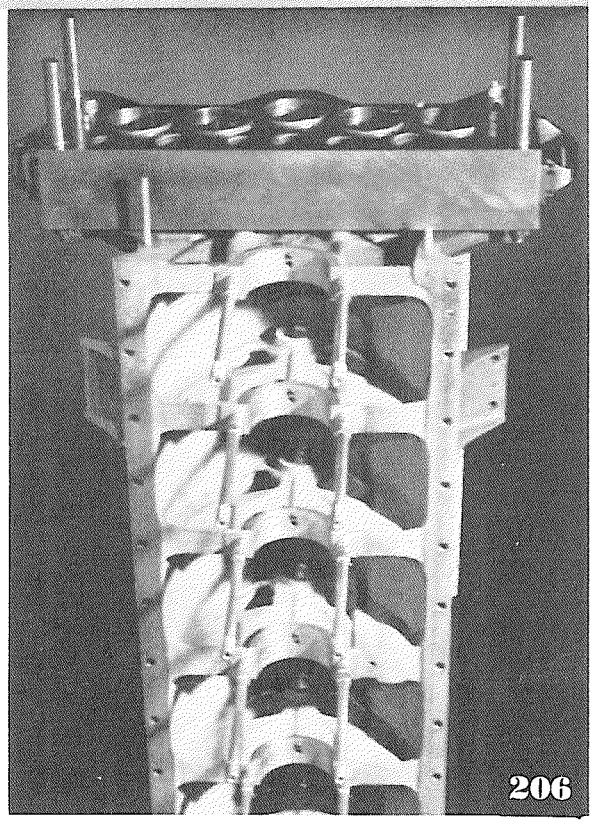
Bolt the upper and lower halves of the main crankcase together by installing the main bearing stud nuts and the parting flange attaching nuts. Bring all nuts to the proper tightening torque.

If the bearing boss to be reworked is in the front crankcase web, clamp Front and Main Crankcase Bearing Rework Jig, AT-423, in position on the front of the crankcase.

If the bearing boss to be reworked is in the rear crankcase web, clamp Rear and Main Crankcase Bearing Rework Jig, AT-424, on the rear of the crankcase. . . .**205**

Refer to the following table for information on the proper size boredrill and for specifications for the reworking of the bearing boss.

Bearing Boss	Face off Below Parting Surface	Boredrill Tool No. and Size	Bore to Depth of—	Chamfer Angle Depth
Front Crankcase Web Accessory Drive Shaft	.094" ± .002"	AT-429 1.219"	Through	45° 3/64"
Upper Idler Gear	.094" ± .002"	AT-426 .937"	29/32"	45° 3/64"
Lower Idler Gear	.078" ± .002"	AT-427 1.000"	15/16"	45° 3/64"
Rear Crankcase Web Accessory Drive Shaft	.406" ± .005"	AT-429 1.500"	Through	45° 3/64"
Rear Idler Gears Right and Left	.406" ± .005"	AT-430 .922"	25/32"	45° 3/64"
Magneto and Tachometer Drive Gear	.406" ± .005"	AT-431 1.125"	Through	45° 3/64"
Magneto and Pressure Oil Pump Drive Gear	.406" ± .005"	AT-431 1.125"	Through	45° 3/64"



Place Facing Cutter, AT-432, in Facing Cutter Holder, AT-444, and chuck holder in a floor type vertical drill press.

Place wooden blocks on the base of the drill press so that the crankcase will be firmly supported in a vertical position on the end parting flange opposite the work . . . . . 206 and align the spindle of the drill with the bearing boss to be reworked. Using the fixture as a guide, reface the bearing boss to the depth specified in the table.

Remove the facing cutter and holder from the drill press. Select the proper boredrill, place in the Boredrill Holder, AT-425, and chuck the holder in the drill press. Rebore the bearing boss oversize to the depth specified in the table.

Remove the boredrill and holder from the drill press. Place the Chamfering Cutter, AT-433, in the Facing Cutter Holder, AT-444. Chuck the holder in the drill press and chamfer the inner edge of the bearing boss to the depth specified in the table.

Chill the replacement bushing in a bath of alcohol and dry ice for twenty minutes, after which it can be tapped into position with a light mallet and flat fiber block, making certain that the oil hole in the bushing lines up exactly with the oil hole in the bearing boss.

REAR CRANKCASE SECTION

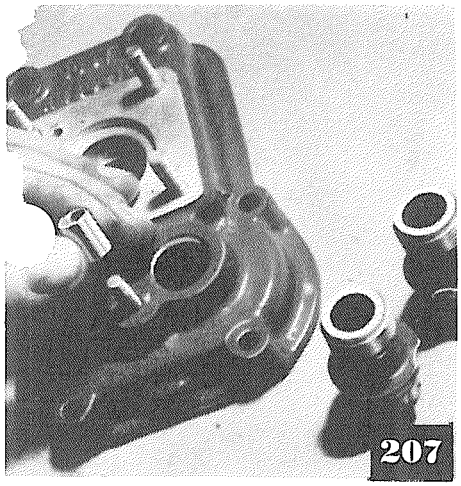
Installation of Replacement Bushings

If inspection has shown any of the bearing boss surfaces in the rear crankcase to be damaged, worn oversize or out of round, the bearing bosses may be rebored to an oversize that permits the installation of a bushing as follows:

Clamp the Rear and Main Crankcase Bearing Jig, AT-424, on the front of the rear crankcase.

Refer to the table below for information on the proper size boredrill and specifications for reworking the bearing boss.

Bearing Boss	Face off Below Parting Surface	Boredrill Tool No. and Size	Bore to Depth of—	Chamfer Angle Depth
Rear Crankcase Section				
Upper Idler Gears Right and Left	.219" ± .005"	AT-430 .922"	25/32"	45° 1/32"
Magneto and Tachometer Drive Shaft	.219" ± .005"	AT-431 1.125"	Through	45° 1/32"
Magneto and Pressure Oil Pump Drive Shaft	.219" ± .005"	AT-431 1.125"	Through	45° 1/32"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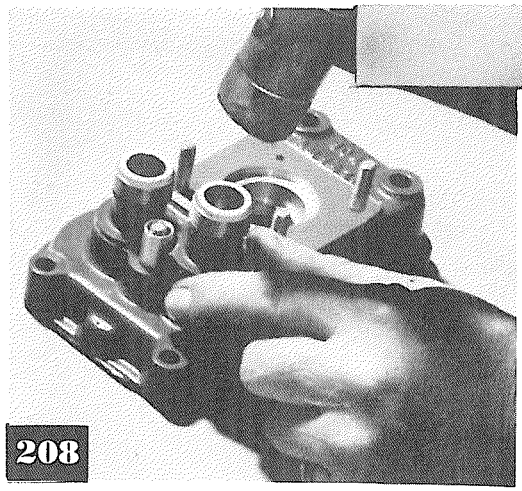
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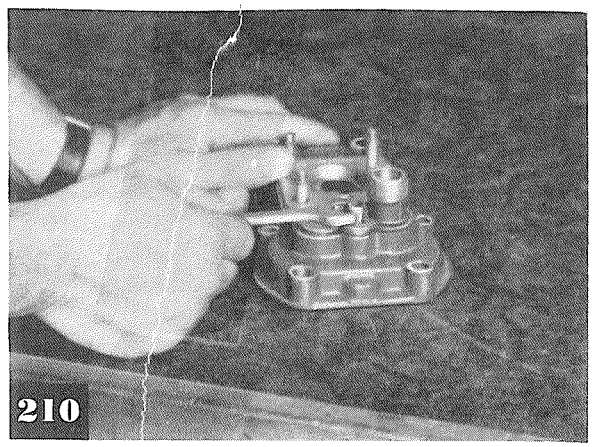
209

Where necessary, all bearing bosses in the rear crankcase may be reworked for the installation of shouldered bushings in accordance with the instructions given for the rear end of the main crankcase.

Vacuum Pump and Tachometer Drive Housing

Place the Tachometer Drive Adapter Guide, AT-208, on the adapter retaining stud. **207**
Put the tachometer drive adapters in their proper positions and drive them into place using a composition mallet. **208**
Remove the guide, and place the retaining washer on the stud. Secure the washer in place using a 1/4 inch self locking nut. If only one tachometer drive is to be used, install the adapter and remove the guide. In place of the second adapter drive in a plug **209**
and lock into position using the retaining washer and nut. **210**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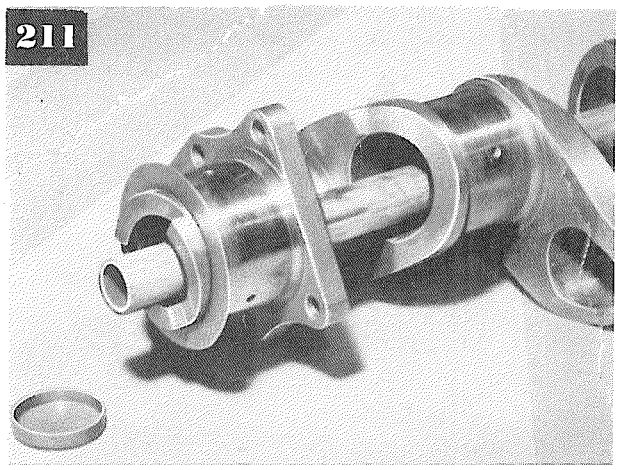
CRANKSHAFTS

Regrinding of Crankshafts

Because of the close engineering control required when regrinding crankshafts, and of the necessity of reshotblasting the shafts after they have been reground, it is advisable to return all crankshafts to the manufacturer for the grinding of main or crankpin journals. Crankshafts which are bent beyond the limits specified in the Table of Limits, should also be returned to the manufacturer to determine whether the shaft may be satisfactorily straightened.

Replacing Starter Jaw

To replace damaged starter driving jaw, tap out the cup plug in the jaw from the front, ... **211**
then drill out the head of the flathead rivet and remove it, using a 1/8 inch pin drift. Pull the damaged starter driving jaw and the starter jaw key out of the crankshaft, using a Starter Driving Jaw Puller, AT-198.
. . . . . **212**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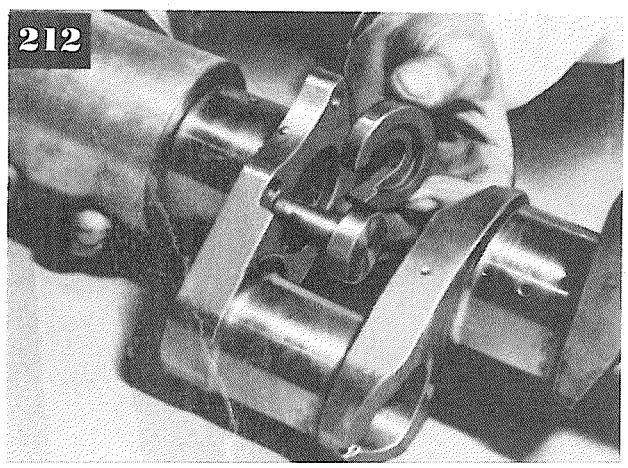
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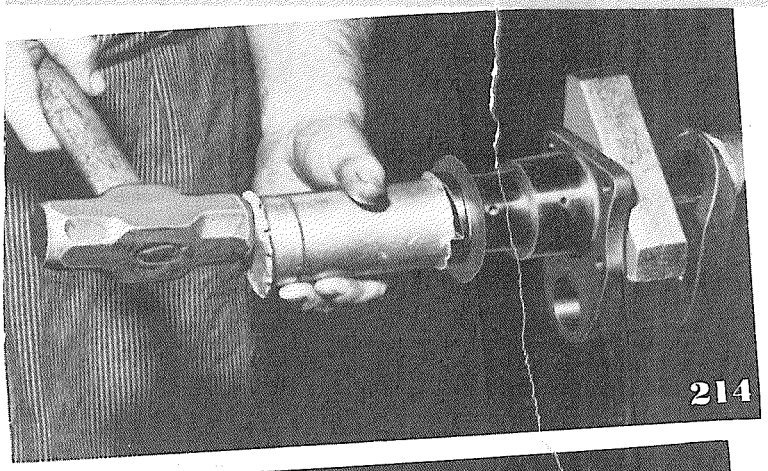
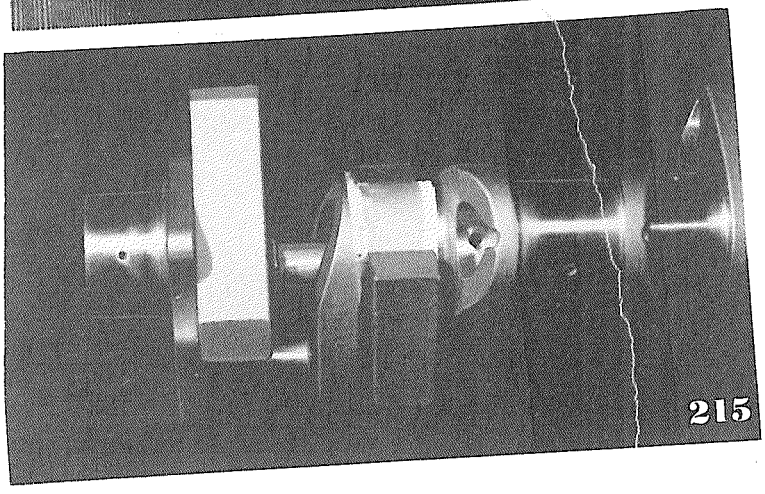
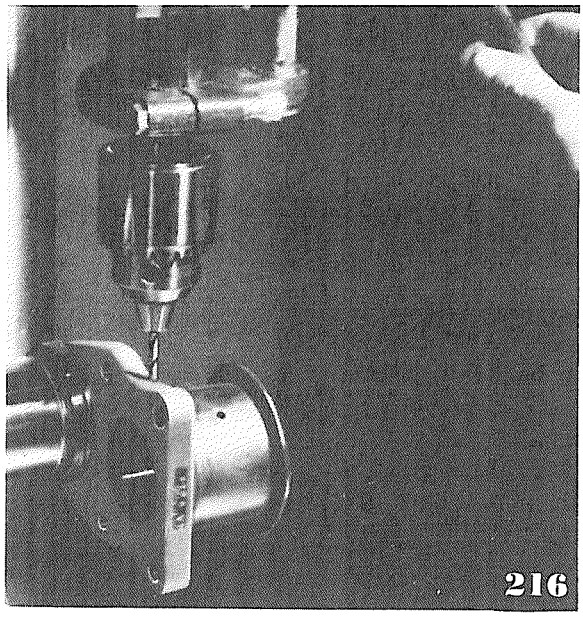
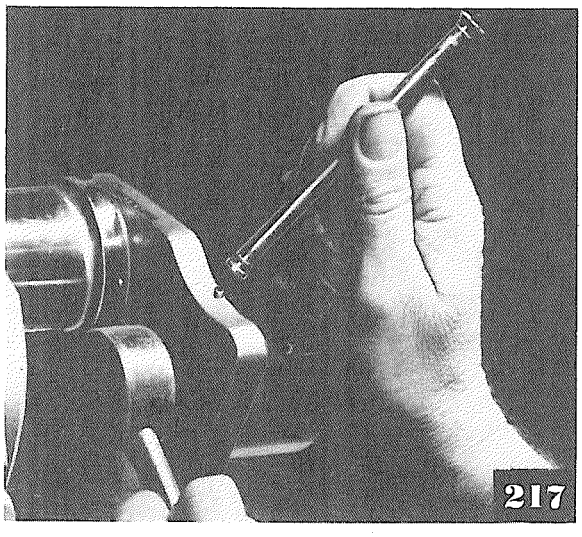
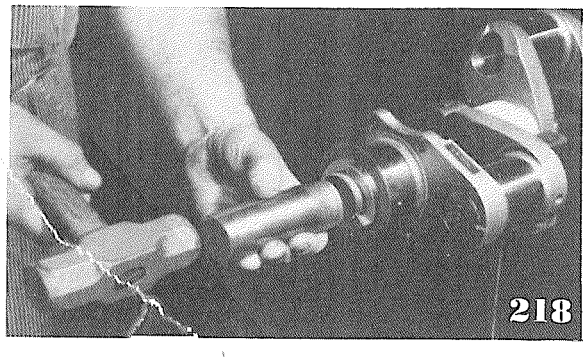










Install a new key in the keyway in the rear of the crankshaft. The key may be filed or stoned to provide a snug fit in the crankshaft keyway. Heat the rear end of the crankshaft in oil to about 232° C. (450° F.). Place the starter drive oil slinger over the starter jaw, insert the key in the keyway of the jaw and drive the assembly into place in the crankshaft, using a Starter Driving Jaw Drift, AT-199. . . . . **214**

To eliminate the danger of forcing the crankshaft out of alignment, the crankshaft should be braced at the damper plate attaching pad, directly ahead of the rear main journal, ... **215** when driving the starter jaw into position. When the starter jaw is in position in the crankshaft, a 1/8 inch hole should be drilled through the starter jaw, using the rivet hole in the crankshaft as a guide. . . **216** Install the rivet from the inside of the starter jaw and form a head on the rivet, using Rivet Backup Tool, AT-200, and Rivet Heading Tool, AT-201. . . . . **217** Using Drift, AT-236, drive a new cup plug into the rear of the starter jaw. **218**

Installation of Balance Plug

If the replacement of a crankshaft should be necessary, it is recommended that a new shaft and balancing plug assembly be installed so as to be sure that all parts will be properly balanced.

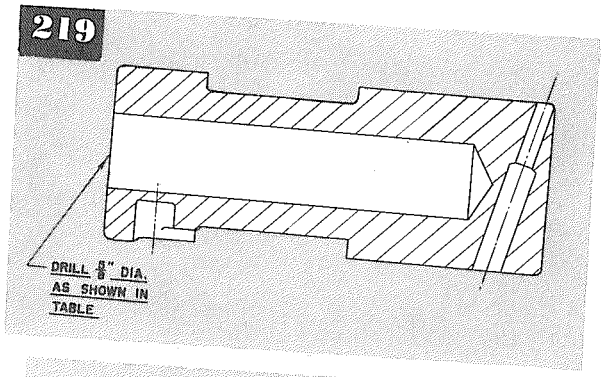
If for any reason it should be necessary to assemble an unmatched crankshaft and balancing plug, make sure that the new plug bears the same "dash" number as that

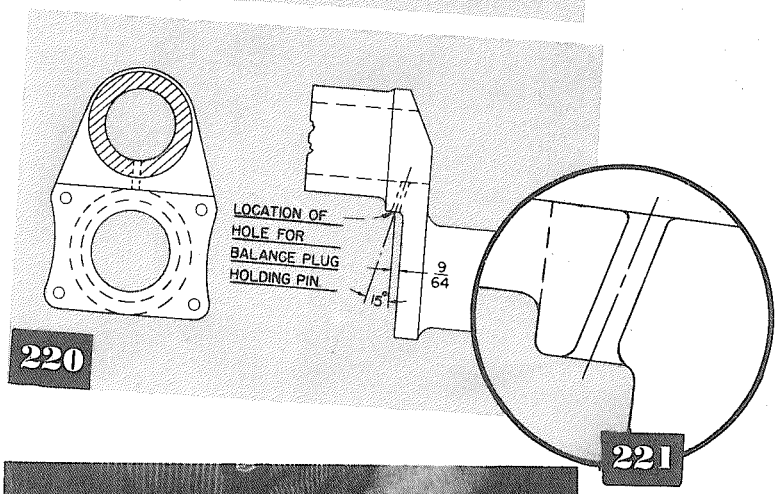
stamped on the side of the No. 1 crankthrow near the balancing plug hole. The "dash" number expresses in eighths of an inch the depth to which the 5/8 inch diameter lightening hole should be drilled in the plug to balance the crankshaft assembly. If only undrilled plugs are available, refer to the following table, which gives the proper drill depth and plug weight for all "dash" numbers.

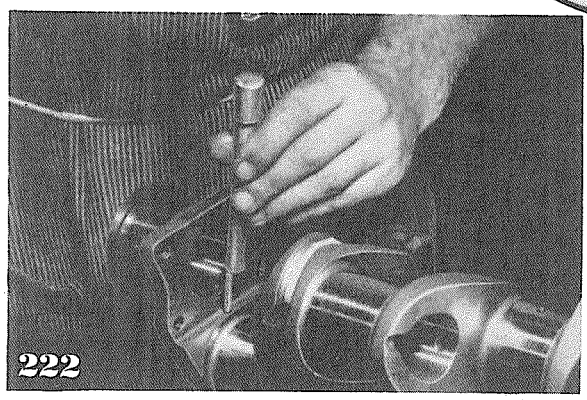
Plug Dash No.	Weight in lbs.	5/8" Drill Hole Depth
1	1.43	1/8"
2	1.42	1/4"
3	1.41	3/8"
4	1.395	1/2"
5	1.385	5/8"
6	1.37	3/4"
7	1.36	7/8"
8	1.35	1"
9	1.34	1-1/8"
10	1.33	1-1/4"
11	1.315	1-3/8"
12	1.305	1-1/2"
13	1.29	1-5/8"
14	1.28	1-3/4"
15	1.27	1-7/8"
16	1.26	2"
17	1.25	2-1/8"
18	1.24	2-1/4"
19	1.23	2-3/8"
20	1.22	2-1/2"
21	1.21	2-5/8"
22	1.195	2-3/4"
23	1.19	2-7/8"
24	1.18	3"

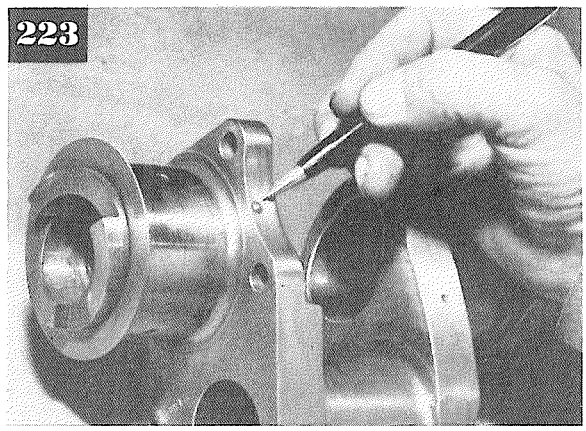
Drill a 5/8 inch diameter hole in the front end of the plug to the depth indicated in the table. **219**
Insert the plug in the No. 1 crankpin, making sure that the recess for the dowel at the front end lines up with the dowel hole. At the location and angle shown in . . . . . **220** drill a 5/32 inch diameter hole through the crankshaft and plug. Drill through the crankshaft and into the plug to a total depth of 1-5/8 inches, using a No. 14 drill. Ream the enlarged portion of the hole to .186 inch ± .0005 inch. Smooth off the outside edge of the hole to obtain a "bellmouth" opening, blending it smoothly into the flat surface of the shaft and into the radius at the edge of the mounting pad. **221**

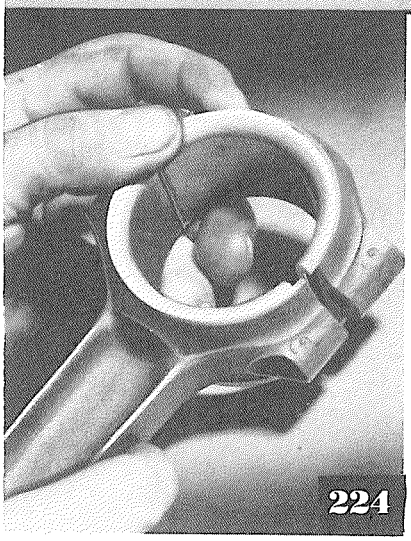
Secure the balance plug in position by driving a 3/16 x 1-1/2 inch pin through the shaft and into the plug. **222**
See that the head of the pin is flush with the edge of the damper plate mounting pad so as not to interfere with the installation of the damper plate. **223**

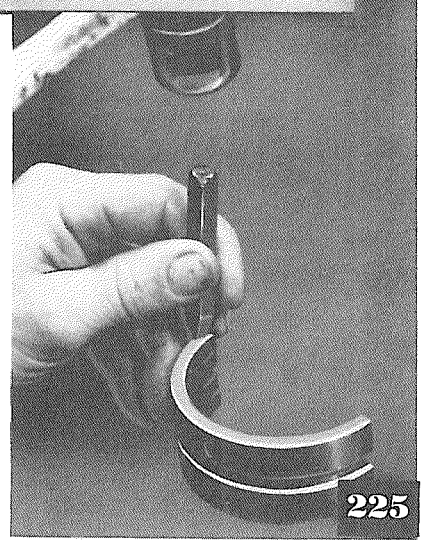


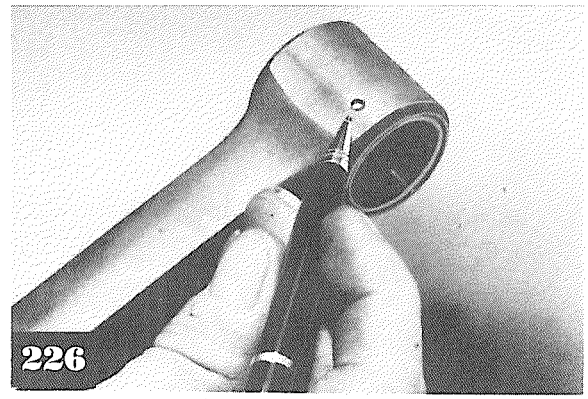


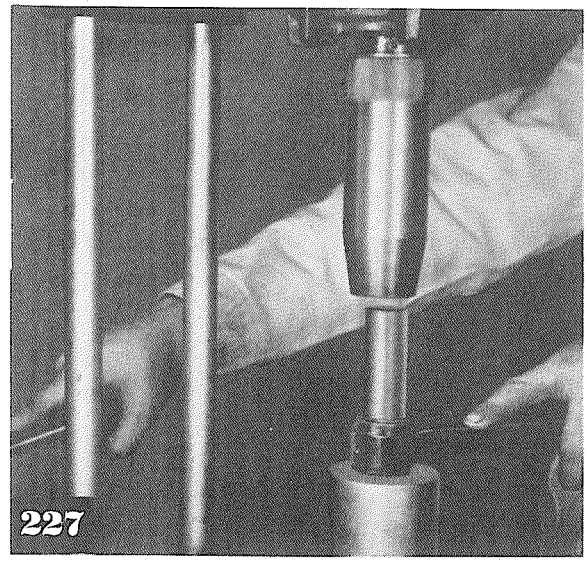












CONNECTING RODS

Bearing Replacement

Old style connecting rod bearings may be replaced by the new type in pairs. The new type bearings have the locating dowel holes drilled 15 degrees off center to effect better alignment and better distribution of bearing loads. The old and new types of connecting rod bearings have the same part number. Connecting rod bearings must be installed with the bearing parting surface within the connecting rod on the same side as the connecting rod number, and within the bearing cap on the unnumbered side. **224**

When connecting rod bearings are replaced, the location number should be stamped on the rear edge of the intake side of each half of the bearing, adjacent to the location number on the connecting rod and cap. **225**

The inside diameter and the alignment of the new bearings should be checked in the manner outlined in the chapter on inspection in this manual. It is recommended that all connecting rod bearings not to be replaced, be burnished.

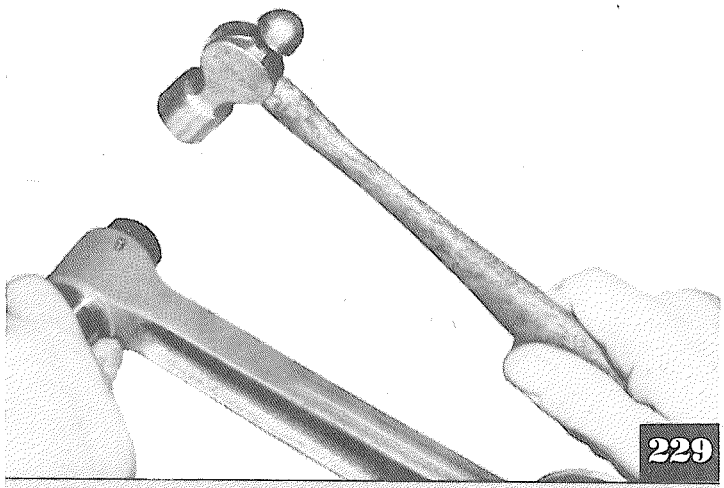
Bushing Replacement

Where it is necessary to replace the connecting rod bushings, the following procedure should be followed:

Drive out the pin retaining the bushing in the connecting rod. **226**

Press out the bushing, using a Drift, AT-110. . . . . **227**

Install a new bushing, using the same method and tools used to remove the old bushing. Using a No. 31 drill, drill through the bushing retaining pin hole in the connecting rod and the piston pin bushing. . **228**



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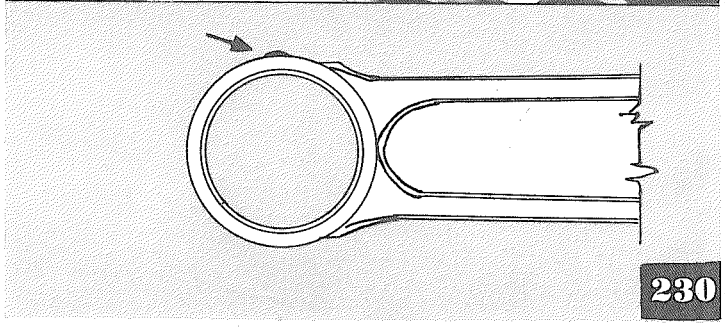


230

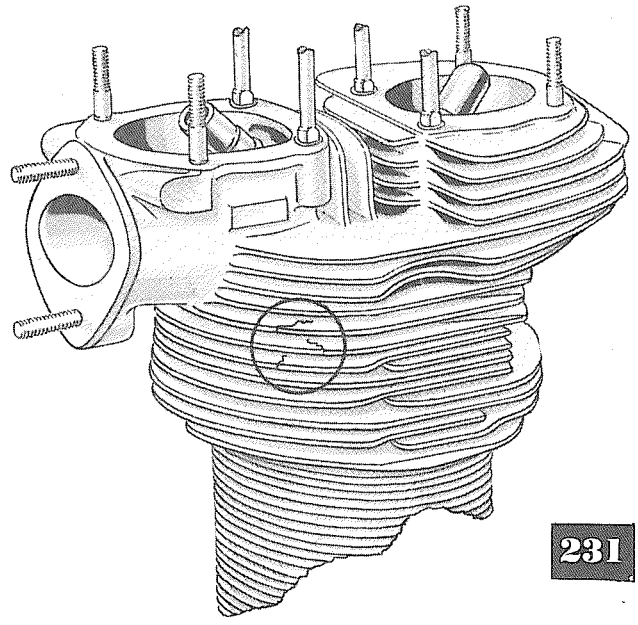
Place a Mandrel, AT-194, in the connecting rod bushing. Anchor the bushing in the connecting rod by driving the retaining pin in the hole solidly against the mandrel, **229** and peen the edge of the hole over the pin. **230**

Piston pin bushings are supplied with an undersize inside diameter and must be bored to size after installation. To facilitate this operation, the connecting rod should be installed in Fixture, AT-483.

The bushing must then be checked for alignment and inside diameter in the manner described in the chapter on inspection.

Correction for Bend or Twist

Should inspection indicate that a connecting rod is bent or twisted, it is advisable not to try to correct this condition by attempting to straighten the rod. Connecting rods that are bent or twisted should be corrected in the following manner. Press out the bushing and check the rod without the bushing for alignment. Should this inspection show that the rod without the bushing is within the limits listed in the Table of Limits in this manual, a new bushing should be installed and line-bored to obtain proper alignment with the connecting rod bearings.



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Connecting rods and connecting rod bearing caps are machined as matched assemblies and, therefore, cannot be replaced as detail parts.

PISTONS

Slight scores on the piston skirt and on the ring lands may be cleaned up with a very light stoning. Deeper scores may be cleaned up only if they appear on the lands above the top ring, between the ring grooves, or below the oil scraper ring, as these lands do not bear against the cylinder walls.

Should inspection show that the piston ring grooves have excessive or uneven width, indicating wear or warping of the lands, the grooves may be cut to an oversize width, after which oversize piston rings must be installed.

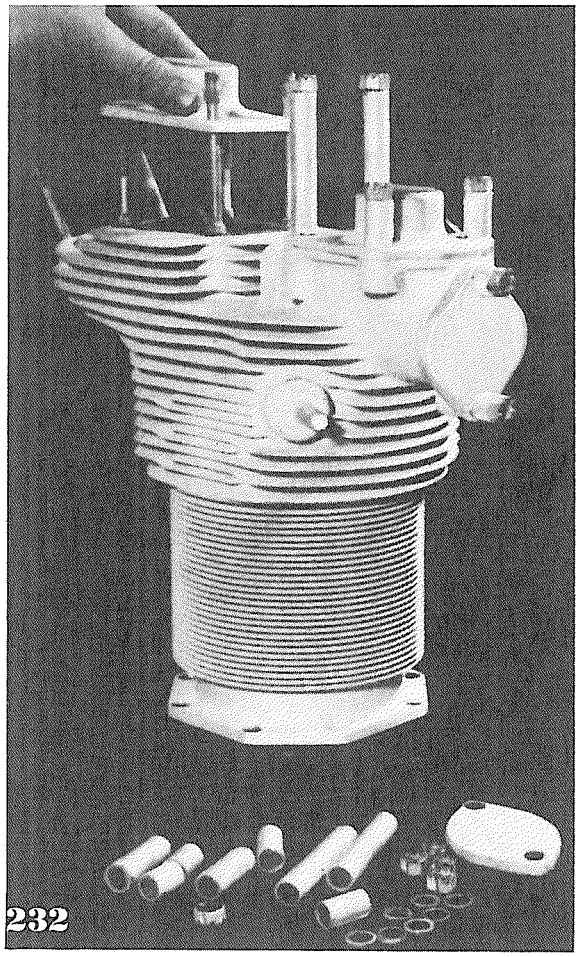
CYLINDER ASSEMBLIES

Scratches on the intake and exhaust ports and slight galling of the parting surface which makes contact with the camshaft housing may be corrected by slight stoning, provided not enough metal is removed to cause a leak. Since any shortening of the distance from the cylinder mounting flange to its top surface would cause distortion and consequent breakage of the camshaft housing, the top surface of the cylinder must not be refaced under any circumstances.

If a few cylinder head fins show small cracks running diagonally across the corners **231**

which may have been caused by handling, the cracked portion should be cut off and the cut edge smoothed off with a file. This procedure may be carried out in only three or four places on any one cylinder head, otherwise the fin area will be so reduced as to affect engine cooling.

Should inspection show that the cylinder finish is thin or has deteriorated in spots, the entire cylinder should be sandblasted and remetallized following the procedures outlined in Chapter I. Before starting to sandblast or remetallize a cylinder, it is important to make sure that the cylinder bore, valve seats, valve guides, spark plugs inserts and all parting surfaces are protected, using Masking Kit, AT-216. . **232** In addition to the masking kit, two rubber oil seals should be used, one around the cylinder barrel against the mounting flange and another in the groove at the end of the masking sleeve that protects the bore of the cylinder.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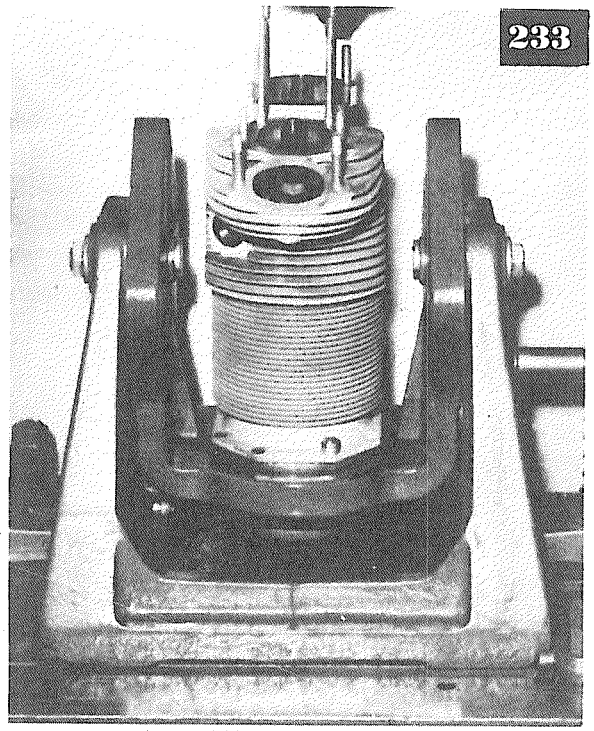
Grinding and Honing of Cylinder Barrels

Cylinder barrels which are worn beyond the permissible limits, may be ground oversize in a standard type of cylinder grinding machine. When setting up the cylinder in the grinder, it is very important to see that the center line of the cylinder is parallel to the center line of the grinder shaft so that an even thickness of metal will be removed from the inside of the cylinder barrel. The grinder should be carefully adjusted so that the stone will grind all the way to the upper edge of the barrel without touching the aluminum head. All cylinders may be ground to .010 inch oversize. Cylinders with the change letter "L" or after can be ground to .010 or .020 inch oversize.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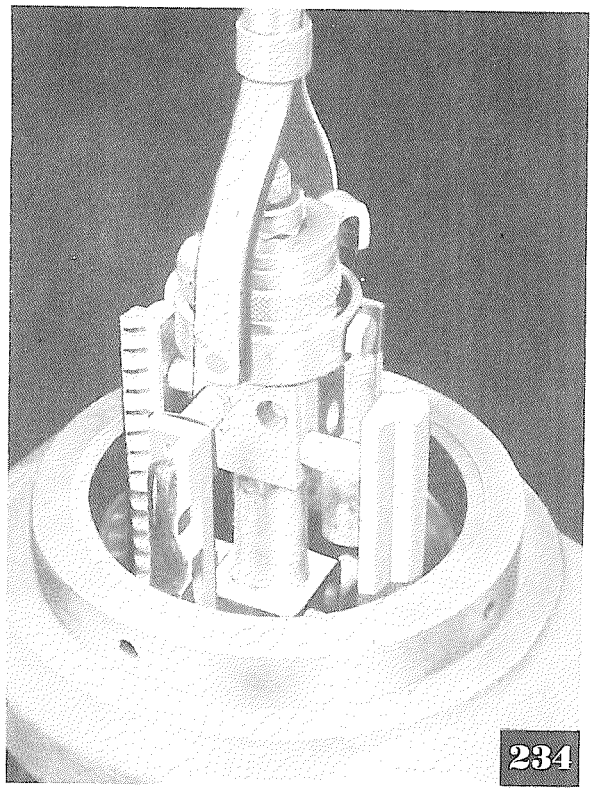
Cylinders which have been reground must be honed after grinding in order to obtain a smoother finish on the inside of the cylinder barrel. Cylinders which have not been reground should also be honed in order to true up the cylinder walls and to provide a satin finish which will help in seating the new piston rings. Honing can be accomplished either in a standard aircraft cylinder honing fixture or by using a portable automotive type hone. The latter should be used in conjunction with Cylinder Holding Fixture, AT-221. Install the cylinder to be honed in the fixture and secure with four cylinder hold-down nuts. . . . . **233** Then rotate the cylinder in the fixture so that the open end of the cylinder is pointing straight up and lock the fixture in this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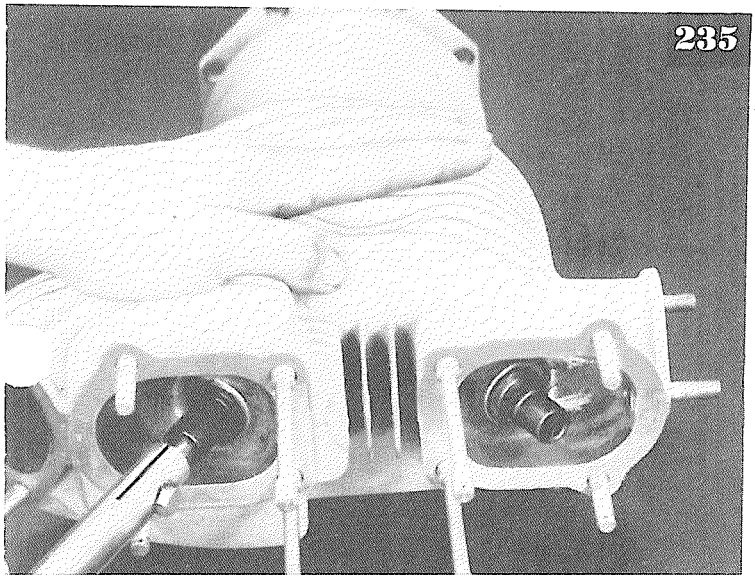
position. Chuck the hone in a slow speed floor type drill press, place the fixture under the hone and carefully lower the hone into the cylinder bore. .....**234** Adjust the stops on the drill press so that the up and down motion of the hone will cover the entire length of the bore without touching the cylinder head. Adjust the speed of the drill press to 400 to 450 R.P.M. Lubricate the cylinder bore with lard or common vegetable fat of equivalent viscosity. During the honing operation raise and lower the hone with a slow, even stroke at a rate of about two full strokes per second. Use a No. 240 (rough) stone until the honed finish covers the entire wall area of the cylinder. Then finish off with a No. 500 (fine) stone.

Lapping and Refacing Valves

It is necessary to lap all valves at overhaul. To do this, first cover the valve to be lapped with a fine grade of valve lapping compound. Insert the valve into the valve guide and install the proper holder. . .**235** For exhaust valves, use Holder, AT-57; for intake valves, use Holder, AT-58. Lap in the valve with a twisting motion of the hand, at the same time holding the valve back against the seat. After every eight or ten strokes, push the valve away from the seat and then draw it back against the seat in a different position. As the amount of lapping required to recondition a valve varies with each valve, the valve being lapped should be removed from the guide and checked at intervals. When it is necessary the exhaust valve may be lapped, using a coarse compound before the fine to remove pit marks. After both valves have been lapped in a cylinder, both the valves and the cylinder must be thoroughly washed with a solvent spray to remove all traces of the abrasive.

Where it is found that valve faces cannot be put into a satisfactory condition by lapping, the valves must be refaced. To reface valves, use a standard valve grinding machine set at 30 degrees for the intake valves, and at 45 degrees for the exhaust valves. .....**236** When valves are refaced, a burred or sharp corner sometimes remains on the upper edge of the ground surface. After refacing, valves will be checked for this condition,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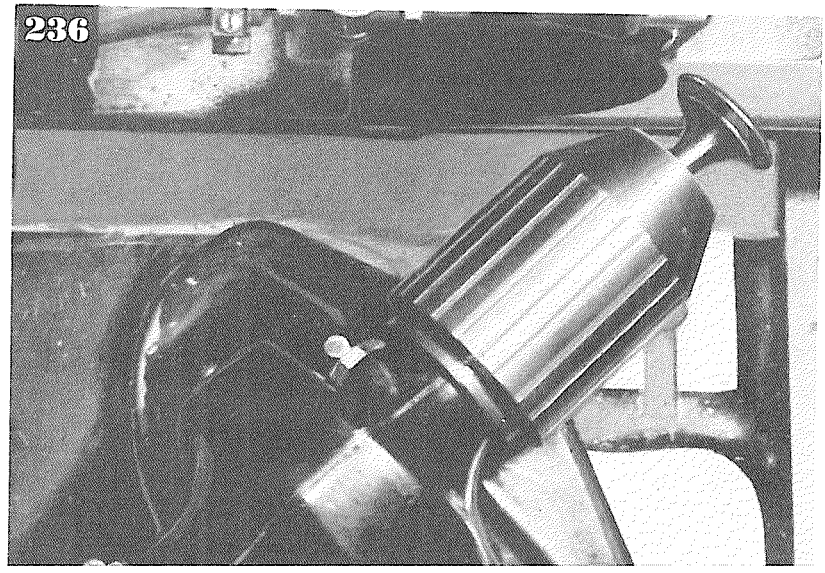
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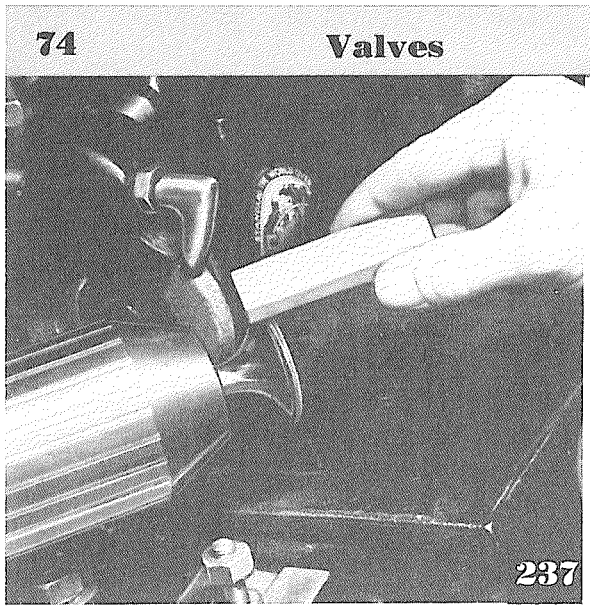
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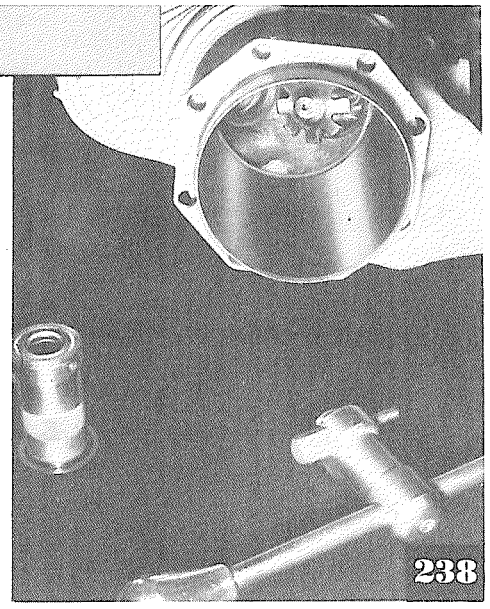
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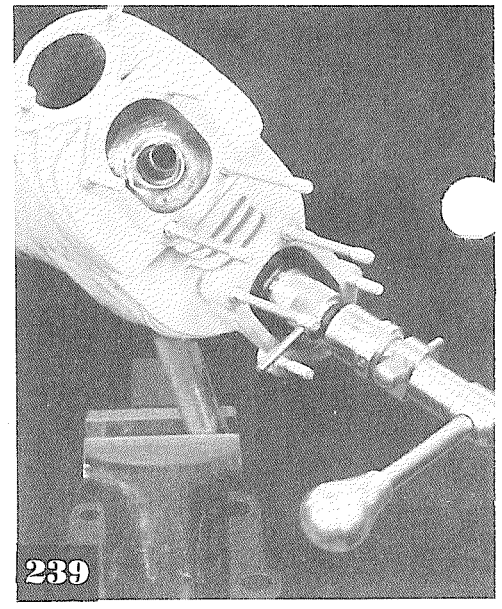
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and, if present, the sharp edges will be removed, using a hand stone while the valve is rotating in the valve grinding machine. **237**

If the valve seats cannot be put in satisfactory condition by lapping, they should be refaced. Reface intake valve seats using Valve Seat Refacing Fixture, AT-237, and Cutter, AT-143. .....**238**

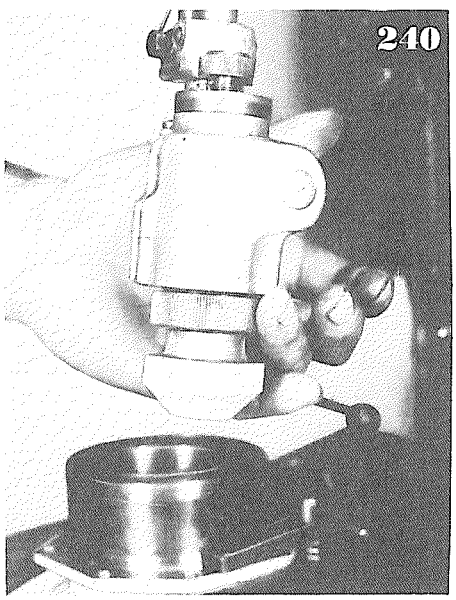
Reface exhaust valve seats 45 degrees using Fixture, AT-237, and Cutter, AT-144, **239** or a Hall Grinder, Model AW or equivalent. **240**

Intake valve seats may be satisfactorily refaced with the Cutter, AT-143, until they have been recut to the extent that the outer edge of the valve seat is 1/16 inch below the surface of the cylinder dome. **241**

Exhaust valve seats may be satisfactorily refaced with the Cutter, AT-144, until they have been recut to the extent that the head of the valve, when closed, is flush with, or below the edge of the contact area. ...**242**

If this condition exists, the edge of the seat above the contact area must be removed, using Exhaust Valve Seat Relieving Cutter, AT-464. Enough material must be cut away so that the face of the valve extends 1/32 of an inch above the contact area of the seat when the valve is fully close. **243**

These two cutting operations can be repeated with satisfactory results until the external edge of the valve seat has been cut to 1/16 of an inch below the surface of the cylinder dome. The exhaust valve seat must then be replaced.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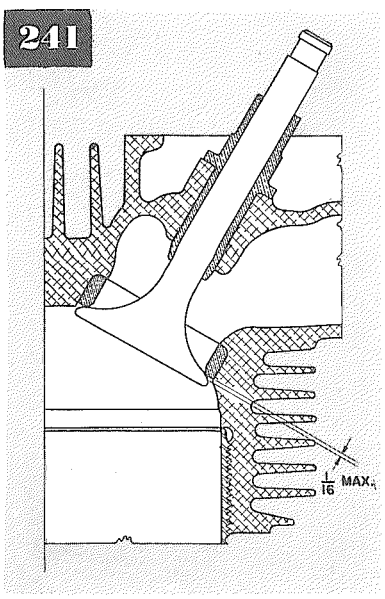

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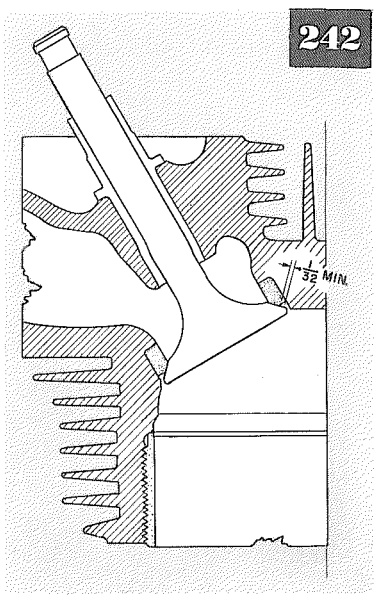

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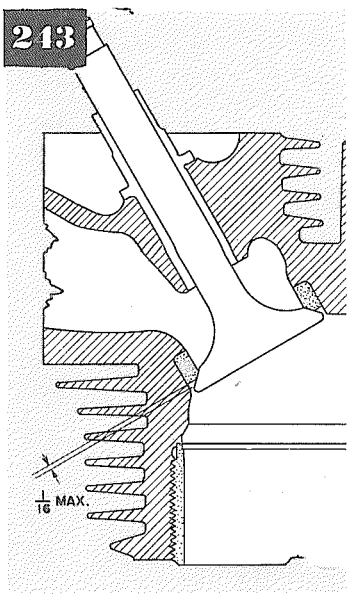

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Valve Seat Replacement

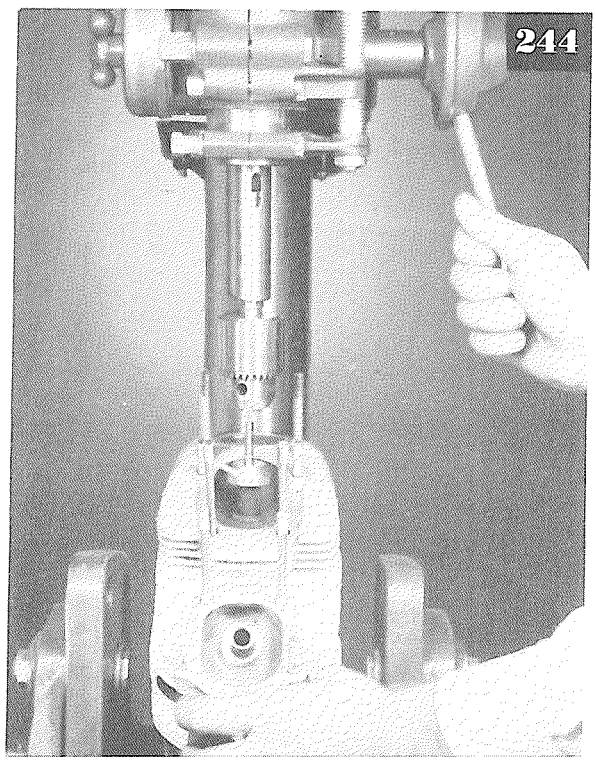
Intake and exhaust valve seats must be replaced when they have been worn or recut to the extent described in the above paragraphs.

If it is necessary to replace the valve seat, mount the cylinder in the Cylinder Holding Fixture, AT-221, in such a position that the valve seat is parallel to the base of the fixture, with the cylinder head facing up. Place the fixture on the table of a vertical drill press.

Select the proper valve seat boring tool. Use an Intake Valve Seat Boring Tool, AT-222, for the intake valve seats, and an Exhaust Valve Seat Boring Tool, AT-223, for the exhaust valve seats. Enter the shaft of the boring tool in the valve guide from inside the cylinder. If the valve guide has been removed, insert the pilot bushing (supplied with the boring tool) in the valve guide hole from the outer end. 244

Adjust the position of the cylinder holding fixture so that the shaft of the boring tool is directly aligned with the spindle of the drill press. Chuck the shaft of the boring tool in the drill press and clamp the cylinder fixture firmly to the drill press table.

Bore the valve seat (intake or exhaust) to a depth of .425 inch ± .005 inch. Take out the boring tool and break out the thin shell that remains, taking care not to damage the hole in the cylinder head. Remove scratches or burrs from the valve seat hole with crocus cloth.

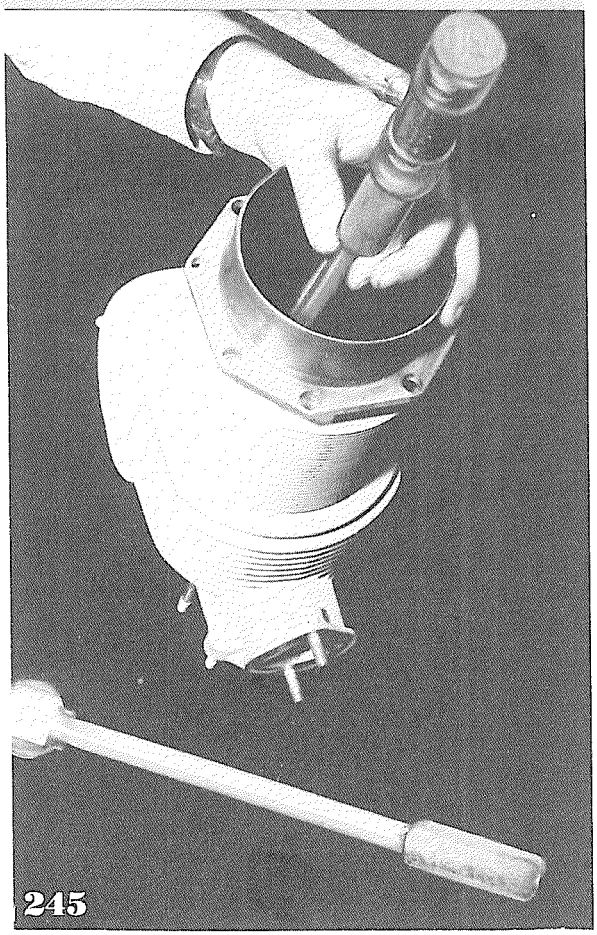


Check condition of valve seat recess and measure inside diameter, making sure the diameter is within the limits specified in the Table of Limits of this manual. If the recess is damaged, enlarged or out of round, it must be rebored with the smallest possible oversize cutter that will produce a clean, round contact area. Refer to the following table which lists the proper oversize cutters to be used.

Tool No.	Tool Name	Oversize
AT-307	Cutter with Holder—Intake Valve Seat Recess Counterbore.	+.005"
AT-308	Cutter — Intake Valve Seat Recess Counterbore.	+.010"
AT-309	Cutter — Intake Valve Seat Recess Counterbore.	+.015"
AT-310	Cutter — Intake Valve Seat Recess Counterbore.	+.020"
AT-311	Cutter with Holder—Exhaust Valve Seat Recess Counterbore.	+.005"
AT-312	Cutter — Exhaust Valve Seat Recess Counterbore.	+.010"
AT-313	Cutter — Exhaust Valve Seat Recess Counterbore.	+.015"
AT-314	Cutter — Exhaust Valve Seat Recess Counterbore.	+.020"

Put cylinder back into the holding fixture and attach the block supplied with the Valve Seat and Valve Guide Rework Pilot, AT-328, on the outer camshaft housing attaching studs on top of the cylinder.

Insert the outer pilot bushing in the block and secure with the attaching nuts.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Insert the proper inner pilot bushing in the outer pilot bushing and enter the proper size recess counterbore from inside the cylinder.

Adjust the position of the cylinder holding fixture so that the shaft of the boring tool is directly aligned with the spindle of the drill press. Chuck the shaft of the boring tool in the drill press and clamp the cylinder fixture firmly to the drill press table. Counterbore the valve seat recess to its full depth. During this operation care must be taken not to undercut the outer edge of the seat recess.

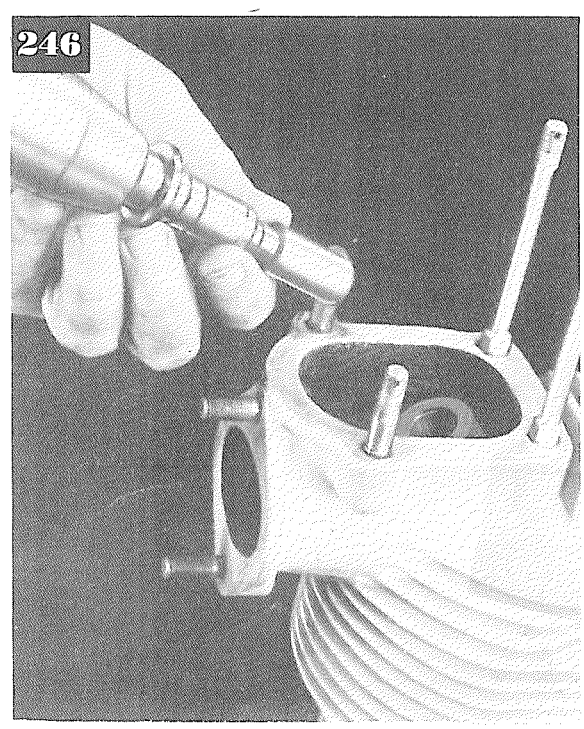
To install a new oversize valve seat, heat the cylinder around the valve seat hole to 218° C. (425° F.) Chill the valve seat in a bath of alcohol and dry ice. Install the valve seat on Valve Seat Holder, AT-224. . **245** Insert the holder into the cylinder so that the pilot enters the pilot bushing, then tap valve seat into position by tapping the end of the holder. Install a nut on the end of the pilot and leave the holder installed until the cylinder cools off.

Lap the new intake and exhaust valve seats lightly as described in previous paragraphs. The intake valve seat should not be lapped any more than is necessary for the valve to make line contact around its entire circumference.

Valve Guide Replacement

If inspection has shown replacement of a valve guide to be necessary, the following procedure should be used. Mount the cylinder in the Cylinder Holding Fixture, AT-221, so that the valve guide to be removed is perpendicular to the base of the fixture with the cylinder head pointing up.

Use an Intake Valve Guide Boring Tool, AT-59, for intake valve guides, and Exhaust Valve Guide Boring Tool, AT-60, for exhaust valve guides. Enter the pilot shaft of the boring tool through the valve guide from the inside of the cylinder and adjust the position of the cylinder holding fixture so that the shaft of the boring tool is directly aligned with the spindle of the drill press. Chuck the shaft of the boring tool in the drill press and clamp the cylinder fixture firmly to the drill press table. Bore out the valve guide from the inner end to within 1/8 of an inch of the shoulder. Remove the boring tool, set a flat headed drift against the shoulder formed inside the guide, and drive the guide out of the cylinder. Check the condition of valve guide hole in the cylinder and measure the inside diameter. **246**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If reworking is necessary, refer to the following table and select the smallest possible oversize reamer to produce a clean, round hole for the next oversize valve guide.

Tool No.	Tool Name	Oversize
AT-320	Reamer — Intake Valve Guide Cylinder Hole Expansion.	+.005"
AT-321	Reamer — Intake Valve Guide Cylinder Hole Expansion.	+.010"
AT-322	Reamer — Intake Valve Guide Cylinder Hole Expansion.	+.015"
AT-323	Reamer — Intake Valve Guide Cylinder Hole Expansion.	+.020"
AT-324	Reamer—Exhaust Valve Guide Cylinder Hole Expansion.	+.005"
AT-325	Reamer—Exhaust Valve Guide Cylinder Hole Expansion.	+.010"
AT-326	Reamer—Exhaust Valve Guide Cylinder Hole Expansion.	+.015"
AT-327	Reamer—Exhaust Valve Guide Cylinder Hole Expansion.	+.020"

After the valve guide hole has been reamed oversize, the proper gage should be selected from the following table and used to check the inside diameter.

To install a new guide, heat the cylinder head around the valve guide hole with a large gas torch flame to 218°C. (425°F.) as indicated by a surface temperature pyrometer. Chill the new valve guide in a bath of denatured alcohol with dry ice.

Install the valve guides, using an Intake Valve Guide Holder, AT-61, for intake valve guides and an Exhaust Valve Guide Holder, AT-62, for exhaust valve guides. Hold valve guide in place with a fiber drift until it expands enough to stay in place.

Tool No.	Tool Name	Oversize
AT-330	Gage — Intake Valve Guide Cylinder Hole Limit Plug.	+.005"
AT-331	Gage — Intake Valve Guide Cylinder Hole Limit Plug.	+.010"
AT-332	Gage — Intake Valve Guide Cylinder Hole Limit Plug.	+.015"
AT-333	Gage — Intake Valve Guide Cylinder Hole Limit Plug.	+.020"
AT-334	Gage — Exhaust Valve Guide Cylinder Hole Limit Plug.	+.005"
AT-335	Gage — Exhaust Valve Guide Cylinder Hole Limit Plug.	+.010"
AT-336	Gage — Exhaust Valve Guide Cylinder Hole Limit Plug.	+.015"
AT-337	Gage — Exhaust Valve Guide Cylinder Hole Limit Plug.	+.020"

Ream the valve guide to size, using an Intake Valve Guide Expansion Reamer, AT-338, for intake valve guides and Exhaust Valve Guide Expansion Reamer, AT-339, for exhaust valve guides. Make a final check on inside diameter of new valve guide using an Intake Valve Guide Standard Plug Gage, AT-220, for the intake valve guides, and an Exhaust Valve Guide Standard Plug Gage, AT-219, for the exhaust valve guides.

Replacement of Spark Plug Inserts

To replace a damaged spark plug insert, clamp the cylinder in the Cylinder Holding Fixture, AT-221, so that the axis of the spark plug insert is perpendicular to the base of the fixture. Place the fixture on the table of a drill press and drill out the spark plug insert, using a Counterbore with 5/8 Inch Pilot, AT-374. Clean out the bronze threads that remain in the cylinder head.

The spark plug insert threads in the cylinder head should now be tapped using the smallest oversized tap which will produce a clean thread. The following is a list of taps available for this operation.

Tool No.	Tool Name	Oversize
AT-378	Spark Plug Insert Hole Tap.	+.005"
AT-386	Spark Plug Insert Hole Tap.	+.101"
AT-387	Spark Plug Insert Hole Tap.	+.015"

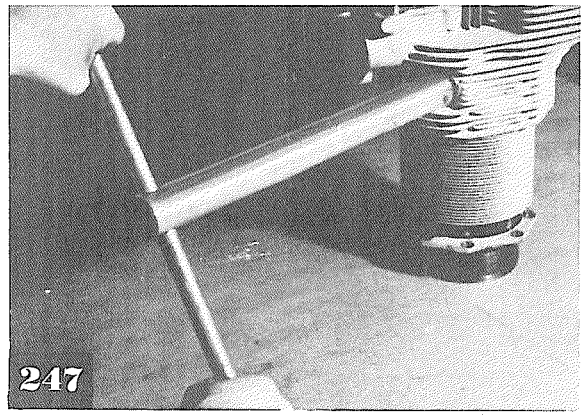
Heat the cylinder head around the spark plug insert hole to 218°C. (425°F.) Chill the new spark plug insert in a bath of alcohol and dry ice and screw it into position using Spark Plug Insert Driver, AT-226. 247
Before removing the driver, it is important to first loosen the driving nut, ...248 so that the spark plug insert will not come out with the driver. Screw the Spark Plug Insert Lock Pin Drill Jig, AT-227, into the spark plug insert and lock it in place. .249 Using a No. 31 drill, drill the two lockpin holes 90 degrees from the former locations to a depth of 3/8 of an inch. Drive the brass lock pins in flush with the face of the insert and remove the jig.

Alignment of Intake Port Flanges

Should inspection show that the intake manifold port flanges are out of alignment, they may be reconditioned by lapping them on a lapping table using a fine lapping compound. 250

CAMSHAFT HOUSING

Slight roughness of the machined surfaces can be stoned out with a fine stone, provided not enough metal is removed to cause an oil leak. If it is found necessary to replace a screw bushing in the camshaft housing, the old bushing should be removed in accordance with the instructions outlined in Chapter I, and the new one installed using a Screw Bushing Driver, AT-235. .251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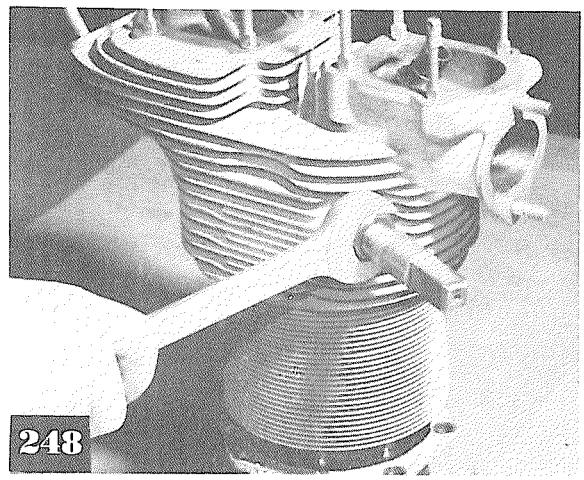
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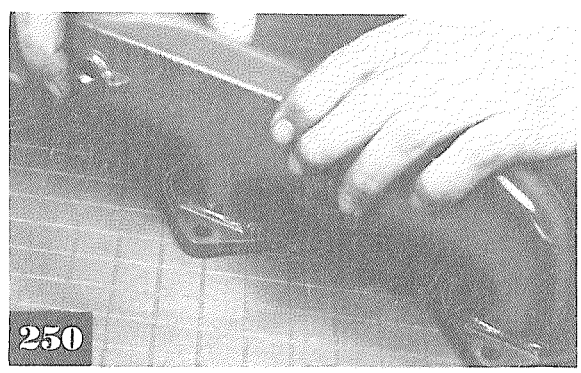
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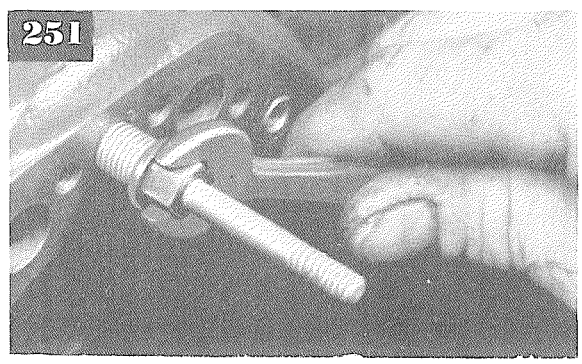
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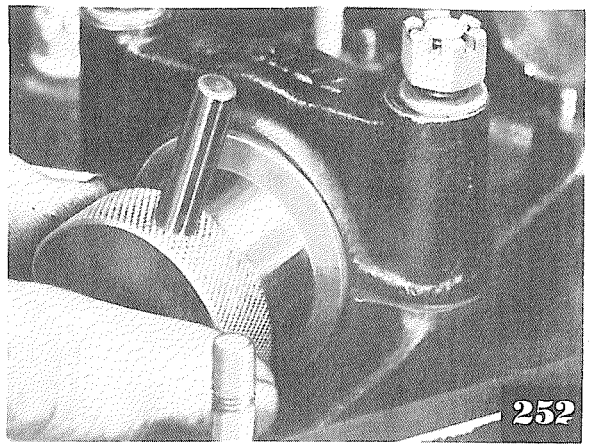
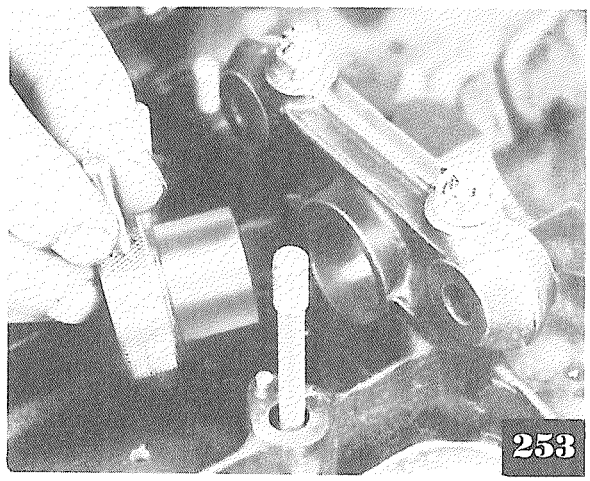
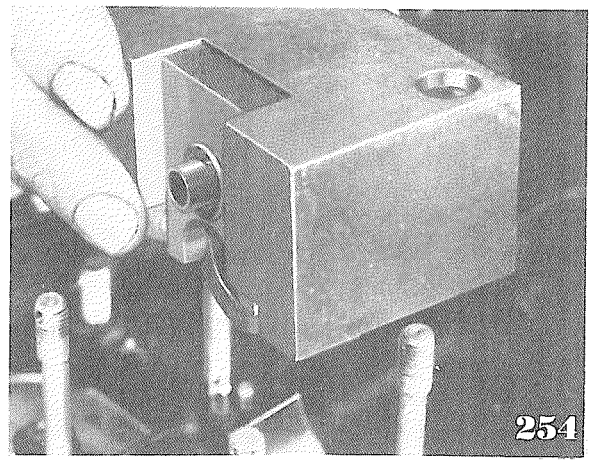
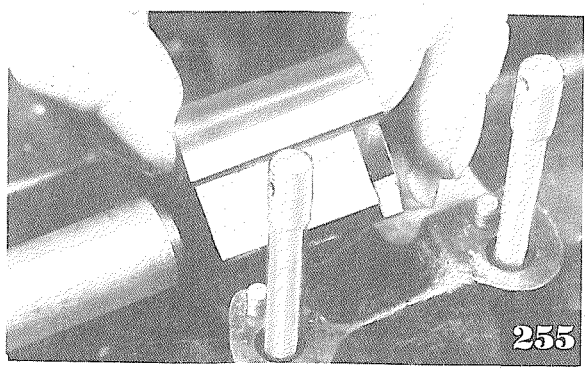
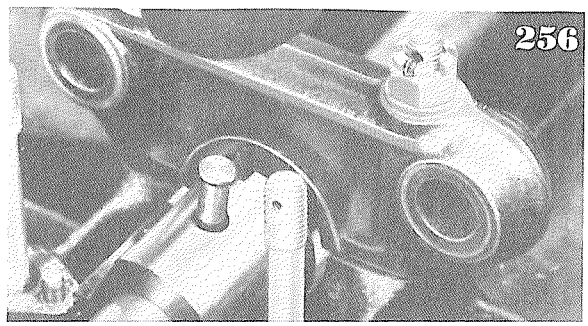










Replacement of Camshaft Bearings

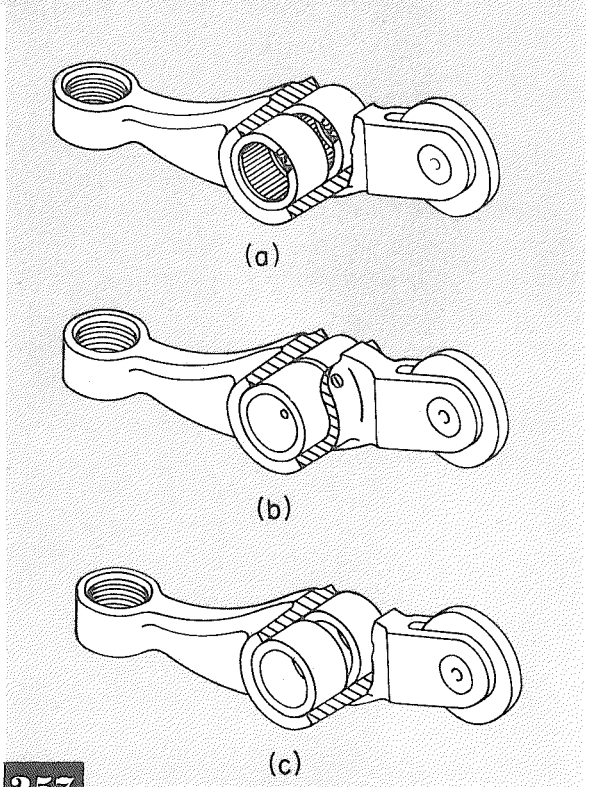
If inspection has shown a camshaft bearing to be damaged, worn oversize, or out of round, the bearings in the camshaft housing and camshaft bearing caps may be line-bored to an oversize that permits split replacement bushings to be inserted. As the camshaft housing is very flexible, it cannot be line-bored without being mounted on a solid base. The procedure for the line-boring operation is as follows:

After the cylinders have been mounted on the crankcase, install the camshaft housing and tighten all the retaining nuts to the specified tightening torque. Install the larger pilot bushing supplied with the Camshaft Housing Bearing Boring Bar, AT-401, in the location at the front of the camshaft bushing. **252**
Install the smaller pilot bushing supplied with AT-401 in number one (rear) camshaft bearing **253**
or, if this is damaged or worn oversize, install it in the next bearing forward which is in good condition. Install the two block fixtures (with the floating pilot bushing) supplied with AT-401 on the camshaft bearing cap studs of the cylinders immediately fore and aft of the bearing to be rebored. .**254**
If number one bearing is to be rebored, install the smaller pilot bushing on number two cylinder, and one block fixture on number three cylinder.

Insert the boring bar supplied with AT-401 through the front pilot bushing and other aligning fixtures, placing Camshaft Housing Bearing Boredrill, AT-402, on the bar immediately ahead of the bearing to be rebored. **255**

Lock the floating bushings to the block fixtures so that the shaft is held in rigid alignment. Pin the cutter to the boring bar **256**
and attach a standard "T" handle with a 1/2 inch drive to the front end of the boring bar. Bore out the camshaft bearing, exerting a steady pressure as the bearing is cut.

Repeat the operation for each bearing to be rebored, shifting the aligning fixtures and the cutter to the necessary positions.



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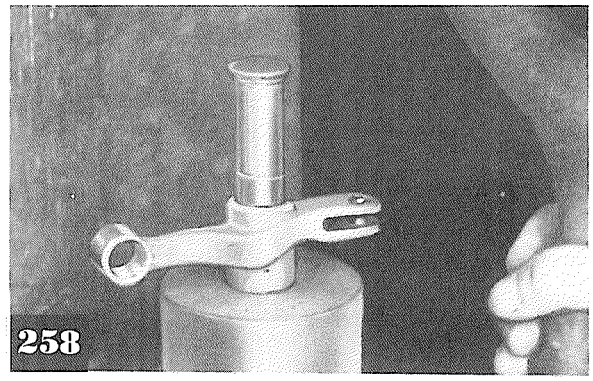
A replacement bushing, Part No. 10292, must be used wherever a bearing and bearing cap have been rebored. The procedure necessary to install these bushings is as follows:

Place the camshaft bearing cap in a vise equipped with copper jaws and place the bushing into the bearing cap. Put the Camshaft Bushing Installation Jig, AT-403, into position and tighten the nuts to insure a proper clamp fit. Place the Center Punch, AT-447, in the two holes drilled in the jig and locate the drill position. Place a Drill Depth Control Sleeve, AT-448, in the recess cut in the top of the jig and, using a No. 31 drill, drill two holes at locations previously marked. After the holes have been drilled, remove the assembly from the vise and stake the bushing in place using a Drift, AT-449, to drive in the pins. Install the other half of the split bushing in the camshaft housing in the same way.

VALVE ROCKER ASSEMBLY

Replacing Bearings or Bushings

Early engines were equipped with needle bearings in the valve rocker assembly. 257a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The bearings were superseded by a one piece bushing, ...257b which was replaced by two short bushings 257c

The needle bearing and the one piece bushing have been discontinued as replacement parts; however, where these parts are still carried in stock, they may be used as replacements. All three types are interchangeable, with the exception that one needle bearing and one short bushing may not be used in the same valve rocker.

Needle bearings must be replaced at each overhaul, while the bushings need be replaced only if they are worn or damaged.

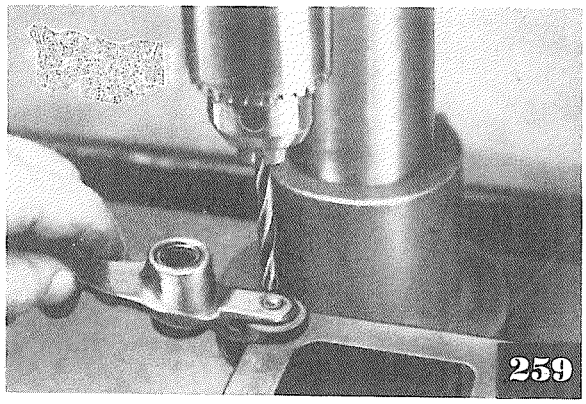
Needle bearings or bushings to be replaced should be removed from the rocker by the use of an Arbor Press and a Drift, AT-451. 258

The same method and equipment should be used to install new bearings or bushings as was used to remove the old ones.

When installing new needle bearings, both bearings must be pressed in separately from the short end of the valve rocker hub with the manufacturer's lettering on the outer races of both bearings facing up. Also make sure that the lettering on one bearing race is directly in line with the corresponding lettering on the other bearing race. 257a

When inserting the short bushings, they must be pressed in from the opposite ends of the valve rocker hub until the outer edge of each is flush with the end of the rocker hub. 257c

After the bushings are installed in the valve rocker, all indications of burrs that might be present on the inside diameter should be removed with a piece of crocus cloth. Also, check the inside diameter against the outside diameter of the valve rocker shaft for fit.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Replacing Valve Rocker Roller

Where it is necessary to replace a valve rocker roller, rivet or spacer, the following steps must be followed.

Place the valve rocker assembly in a vise equipped with copper jaws. Drill out the rivet, using a 1/4 inch drill .....**259** and then remove the roller and spacer. Remove the rocker arm from the vise and, setting the new parts in position, place the assembly on an Anvil, AT-453. Using a Punch, AT-454, form a head on the rivet. .....**260** Remove the assembly from the anvil and check the roller for freedom of movement.

PRESSURE OIL PUMP

Whenever it is necessary to replace the old style, keyed-type gear and shaft with the splined type, it is also necessary to install a bronze bushing in the pressure oil pump housing. This bushing may be tapped into place with a composition mallet, ...**261** as it is not necessary to chill the bushing or heat the housing to obtain a snug fit.

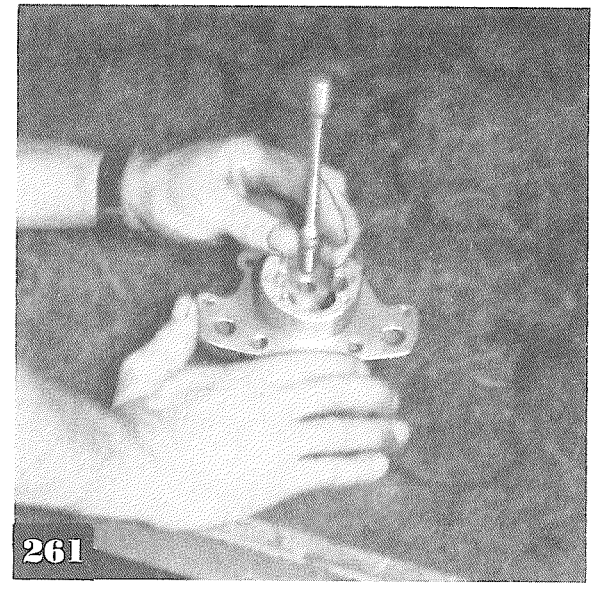
260

IGNITION HARNESS

There are two types of ignition harness and two styles of magnetos applicable to the 6-440C series engine. The harness may either be radio shielded or plain wiring, and the magnetos may be of Scintilla or Edison-Splitdorf manufacture.

If radio shielded wire is to be used, the type of magneto should be checked and the wire cut to the lengths specified in the following table. As each length of wire is cut, it should be immediately tagged as to number of cylinder and the side of the engine on which it will be used.

Cylinder Number	Scintilla Magneto	Edison-Splitdorf Magneto	Magneto Terminal Number
1 Intake side	45 in.	38 in.	1 Left
2 Intake side	39 in.	31 in.	5 Left
3 Intake side	37 in.	30 in.	3 Left
4 Intake side	38 in.	29 in.	6 Left
5 Intake side	45 in.	36 in.	2 Left
6 Intake side	51 in.	42 in.	4 Left
1 Exhaust side	43 in.	34 in.	1 Right
2 Exhaust side	39 in.	29 in.	5 Right
3 Exhaust side	39 in.	30 in.	3 Right
4 Exhaust side	44 in.	36 in.	6 Right
5 Exhaust side	49 in.	41 in.	2 Right
6 Exhaust side	54 in.	46 in.	4 Right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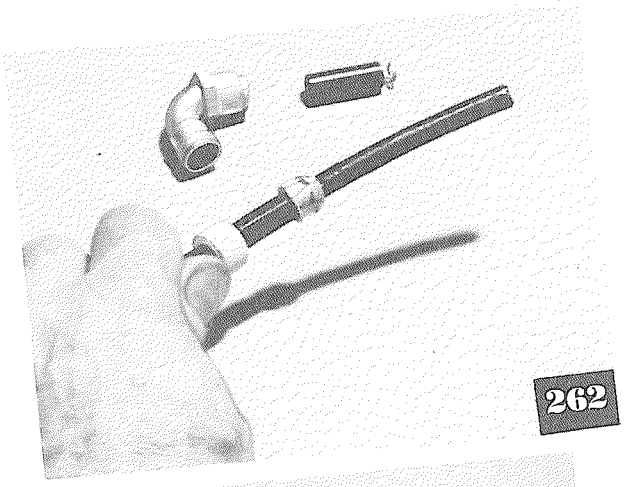
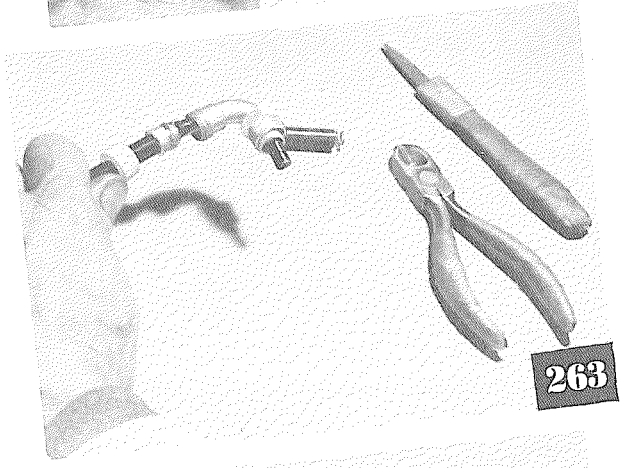
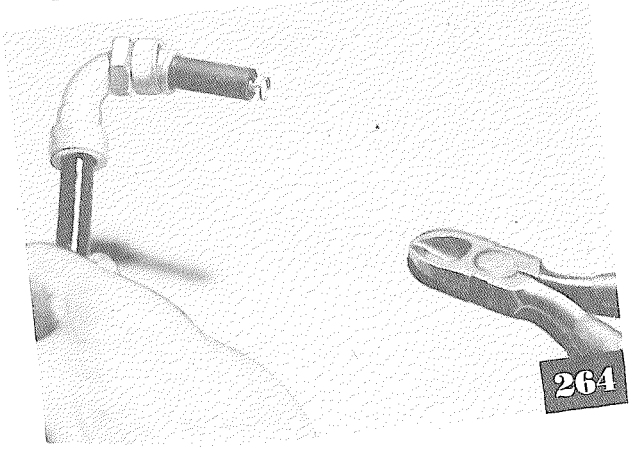
After the wire has been cut, strip the outer insulation for 2-5/8 inches, the shielding for 2-3/8 inches, and the inner insulation for 3/8 inch.

Place the nut and then the cone on the wire and fold the shielding back over the cone. **262**
Insert the wire in the spark plug elbow being careful not to damage the inner insulation, ...**263**
and tighten the nut on the elbow.

Slip the spark plug insulating sleeve over the short end of the wire extending through the elbow. **264**
Bend over the ends of the strands but do not solder them.







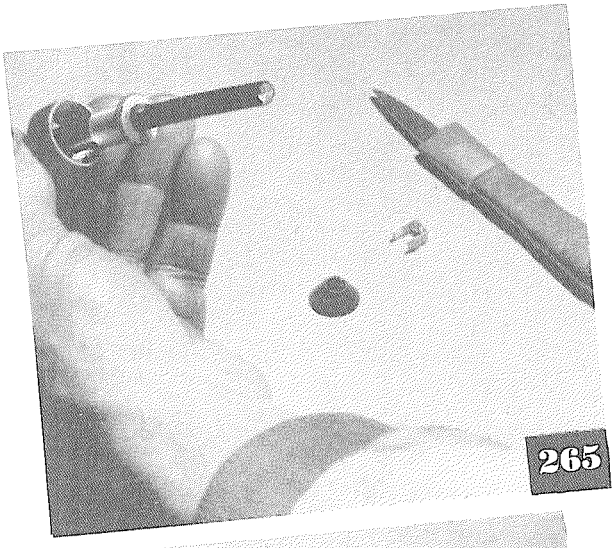
Install a complete new set of grommets in the manifolds. Push the wires individually through the lower manifold, making sure that each one is entered in its proper location. Do not pull the wires as this will break the bond between the metal strands and the insulation.

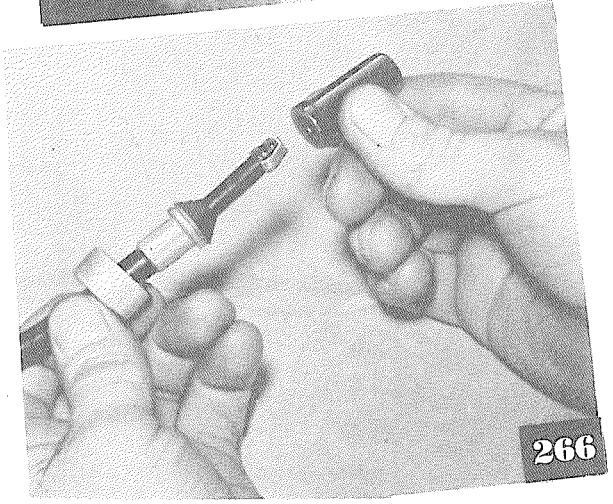
Feed the full sets of wire through the upper manifolds. Install the magneto terminal number sleeves on the wires in accordance with the above table.

Strip the outer insulation for 1-3/4 inches, the shielding for 1-1/2 inches and the inner insulation for ¼ of an inch.

Place the nut and the ferrule on the wire and turn the shielding back against the ferrule. **265**
Install the gasket, magneto terminal clip and the magneto terminal. **266**
Do not solder wires to magneto terminal clips.

Check all wires electrically to see that there are no leaks, breaks or short circuits, and that the numbers on the magneto ends correspond with the correct wire outlet position at the spark plug ends.





If an unshielded ignition wiring assembly is used, cut a new set of ignition wires to the lengths specified in the following table. As each length of wire is cut, it should be tagged as to the number of the cylinder and side of engine on which it will be used.

Cylinder Number	Scintilla Magneto	Edison-Splitdorf Magneto	Magneto Terminal Number
1 Intake side	41 in.	35 in.	1 Left
2 Intake side	37 in.	28 in.	5 Left
3 Intake side	34 in.	27 in.	3 Left
4 Intake side	34 in.	30 in.	6 Left
5 Intake side	41 in.	41 in.	2 Left
6 Intake side	47-½ in.	40 in.	4 Left
1 Exhaust side	39 in.	31 in.	1 Right
2 Exhaust side	35 in.	28 in.	5 Right
3 Exhaust side	35 in.	28 in.	3 Right
4 Exhaust side	39 in.	34 in.	6 Right
5 Exhaust side	45 in.	40 in.	2 Right
6 Exhaust side	50-½ in.	43 in.	4 Right

After the wire has been cut to the proper lengths, strip the insulation for 1/4 inch and insert wires in spark plug terminals. 267

Bend over the ends of the strands and solder the wire to the spark plug terminals.

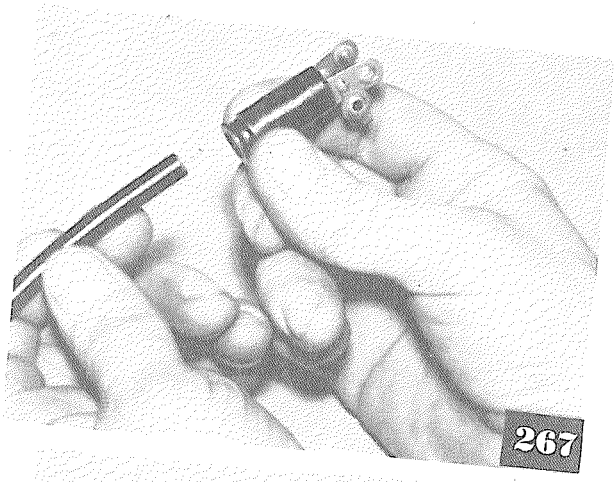
Install a complete new set of grommets in the manifolds. Push the wires individually through the lower manifolds, making sure that each one is entered in its proper location. Do not pull the wires as this will break the bond between the metal strands and the insulation. Feed the full sets of wires through the upper manifolds and install the magneto number sleeves on wires in accordance with the information given in the above table and remove temporary identification tags.

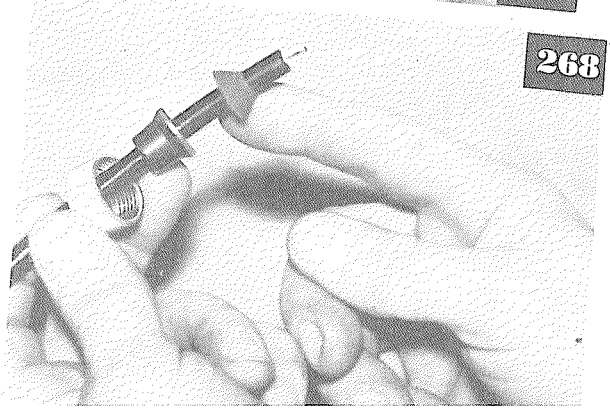
Strip the insulation for 1/4 inch and install the nuts, ferrules and rubber gaskets on the wires. 268

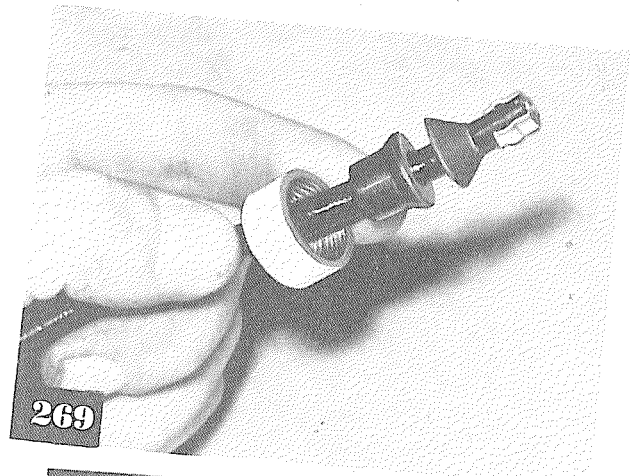
Install the ignition wire terminal clips and bend the ends of the strands over the clips. 269

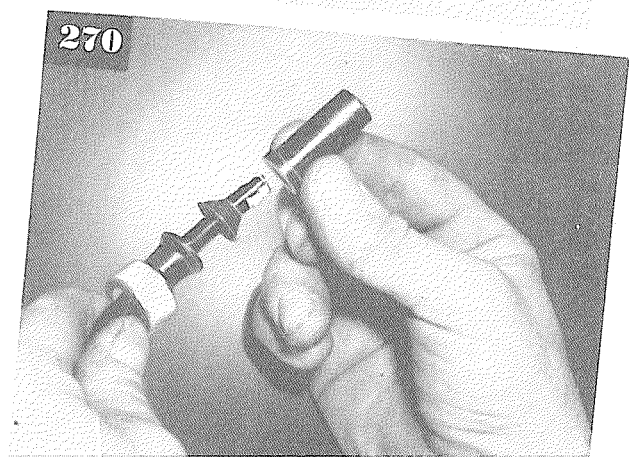
Do not solder the wires to the magneto terminal clips. Install the magneto terminals. 270

Check all wires electrically to see that there are no leaks, breaks or short circuits and that the numbers on the magneto ends correspond with the correct wire outlet position at the spark plug end.

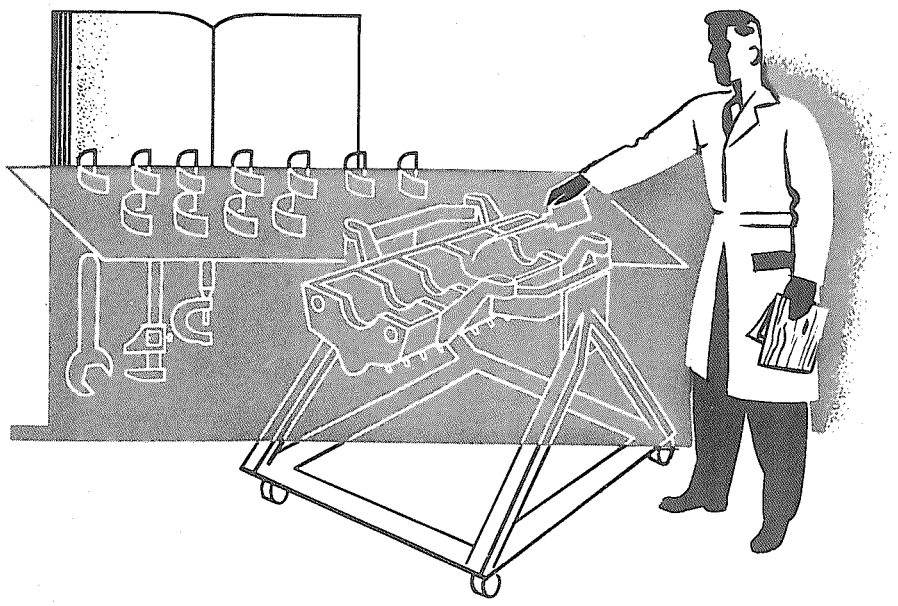








CHAPTER V



ASSEMBLY

This chapter contains the detailed instructions necessary to properly reassemble the engine. Only such inspection measures and tests as are incidental to the assembly procedure are included in this section. No directions for replacement are given here, as the disposition of worn or damaged parts found by inspection must be completed before starting to assemble the engine. A complete list of special tools required for the assembly of the engine is included in Chapter VIII of this manual. The Table of Limits (Chapter IX) should be consulted frequently to make certain that the proper fits and clearances are maintained throughout assembly.

It is important to make sure that all parts are thoroughly clean as they are assembled. All moving parts and bearing surfaces must be coated with a good grade of lubricating oil to prevent damage caused by undue friction when the engine is started.

Wherever possible, all openings should be covered to prevent dirt, dust or small parts from falling into the partly assembled engine.

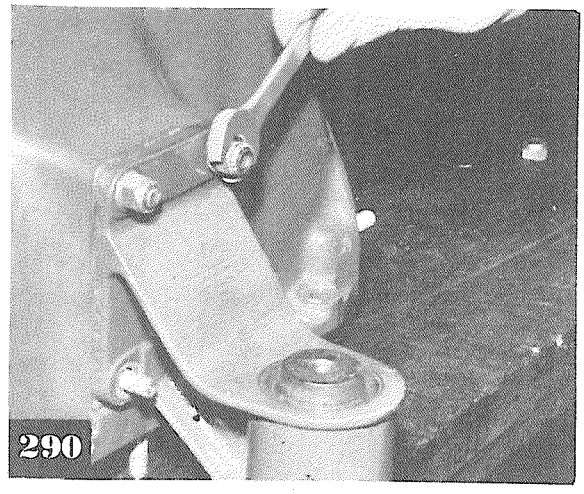
Lockwire, lock washers, cotter pins or palnuts should never be used a second time. All other special safety devices which have been bent or show signs of wear should be replaced.

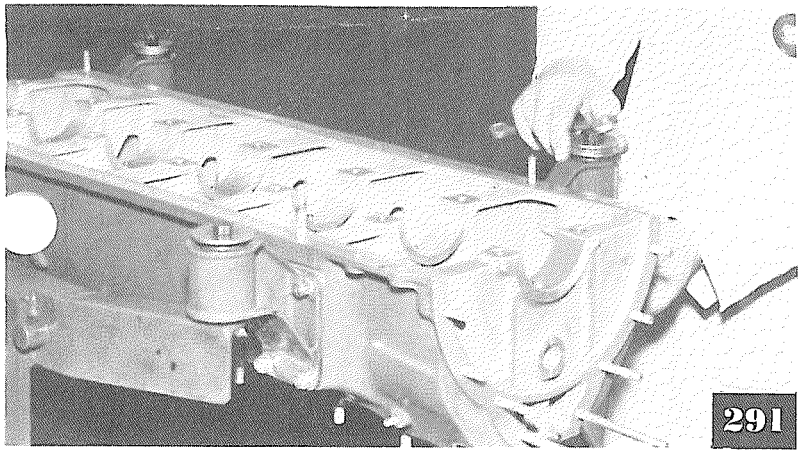
Sealing compound should be used on all parting surfaces where gaskets or oil seals are not used.

MAIN CRANKCASE, CRANKSHAFT AND CONNECTING RODS

Lower Crankcase

Install the engine mount brackets in their proper position on the lower crankcase casting **290**

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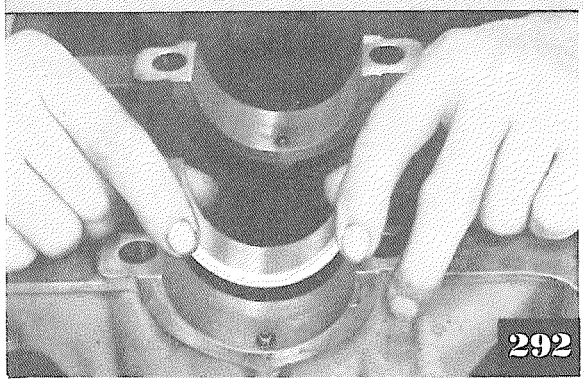

292

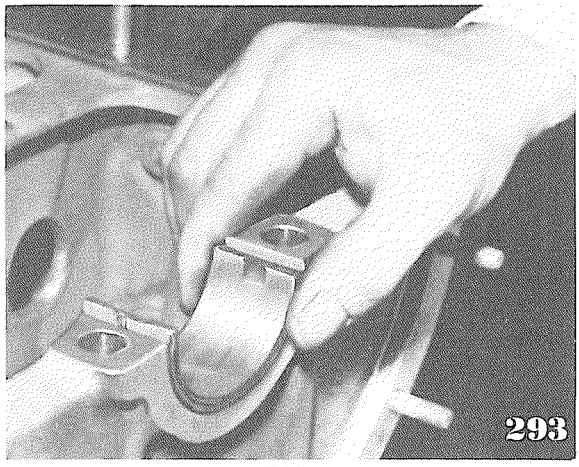
and tighten the four attaching nuts to their proper torque. Place the lower crankcase on the engine assembly stand, securing it in position with the four mounting bolts and nuts 291

When placing the lower crankcase section on the engine assembly stand, make sure that the front of the crankcase is toward the front of the stand.

Place the lower half of the main bearings in the crankcase, making sure that each bearing is in its proper location and position 292

Coat all the bearings and bearing seats and fill all the oil passages with lubricating oil. Early type main crankshaft bearings may be replaced with the new type in pairs. The new type bearings have the locating dowel holes drilled 5 degrees off center to effect better bearing alignment and a better distribution of bearing loads.....293

When installing the new type bearings, the parting surfaces of the bearings will be inside the lower crankcase on the intake side and inside the upper crankcase on the breather side.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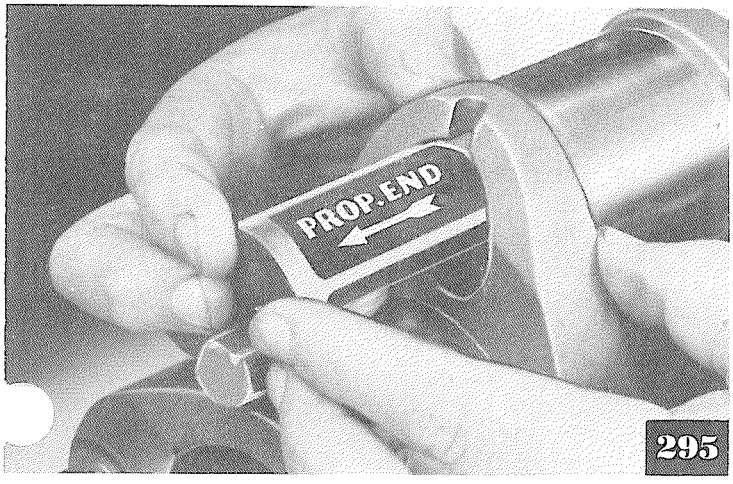

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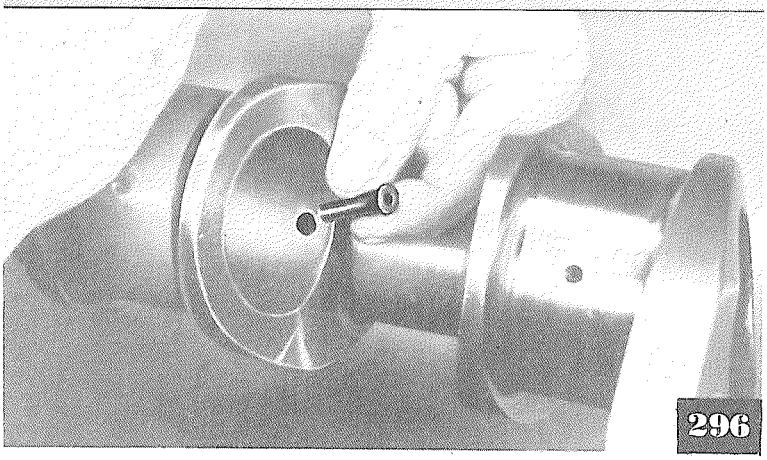
Whenever new bearings are installed, they should have the location number stamped on the rear edge of each half, near the parting surfaces on the intake side 294

Crankshaft

Place the crankshaft assembly on the crankshaft assembly stand. Put all crankshaft plugs in a bath of alcohol and dry ice to chill. When they are thoroughly chilled, install the small plugs in the crankpin journals, making sure that the arrows point toward the front.....295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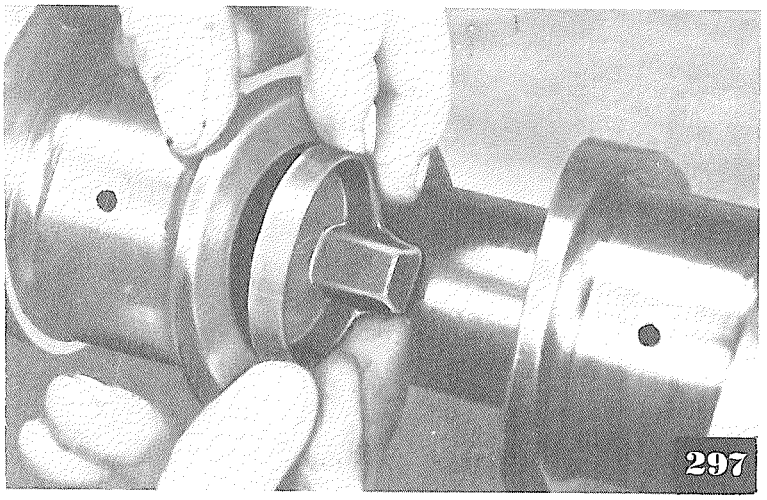
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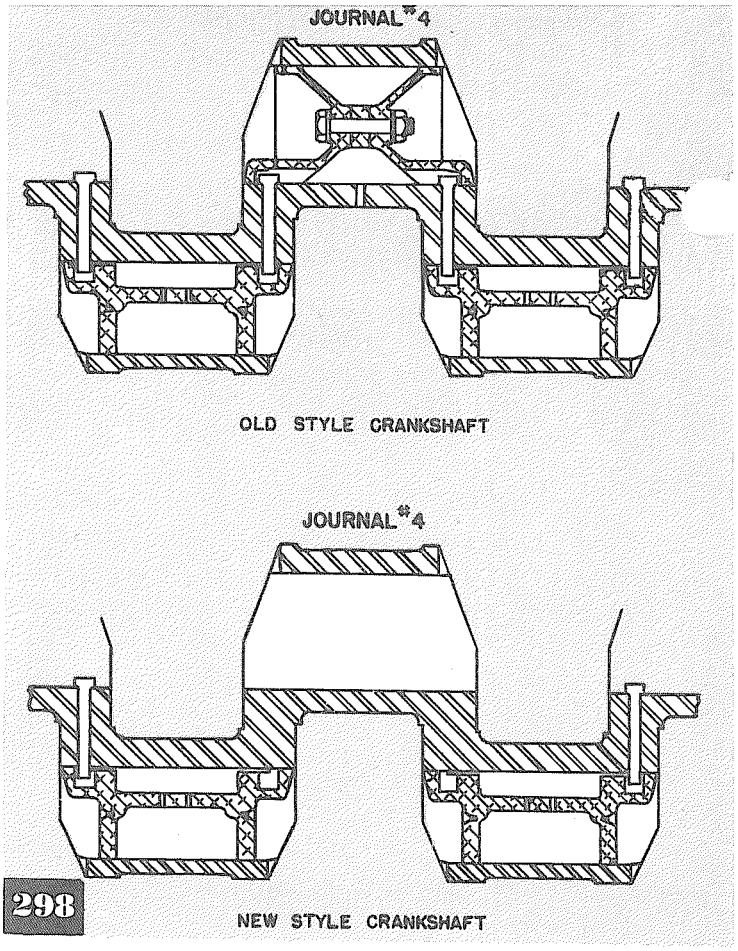
and that the recesses in the outer surfaces at each end are in line with the oil passage holes in the journals. Where it is necessary, the plugs may be tapped into place with a composition mallet. Check the fit of each plug in the journal and see that there are no damaged edges which might cause oil leakage or excessive oil flow.

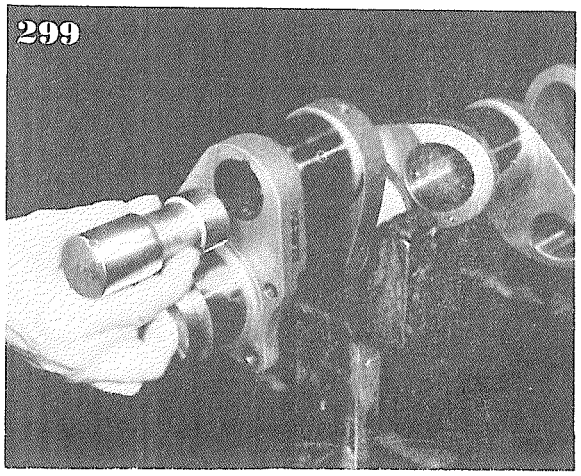
Install the hollow crankshaft dowel plugs from inside the main bearing journals .....**296** When the small plugs are aligned, the shoulders of the dowel pins will seat on the inner surface of the crankshaft main journals.

Install the large crankshaft plugs...**297** following the procedure used to install the small plugs. Install the bolts holding the large crankshaft plugs in place, using a washer under the bolt head and under the nut. Tighten the nut and safety with a cotter pin. A 1/4" spacer must be installed between the two plugs in No. 4 main journal of all crankshafts which require these plugs.



New style crankshafts have the dowel holes, plugs, dowels and related parts removed from the No. 4 main journal...**298** The new and old style crankshafts are interchangeable and have the same part number. Where an old style crankshaft is replaced by the new type, under no circumstances shall the plugs be installed in the No. 4 main journal, as there will be no dowels to hold them. Loose plugs would, therefore, be free to slide backward or forward and cause possible damage to the connecting rod.

Install the balancing plug in the No. 1 crankpin journal, making sure that the hole for the locating pin lines up with the corresponding hole in the crank cheek...**299** Drive in the locating pin with a fibre drift.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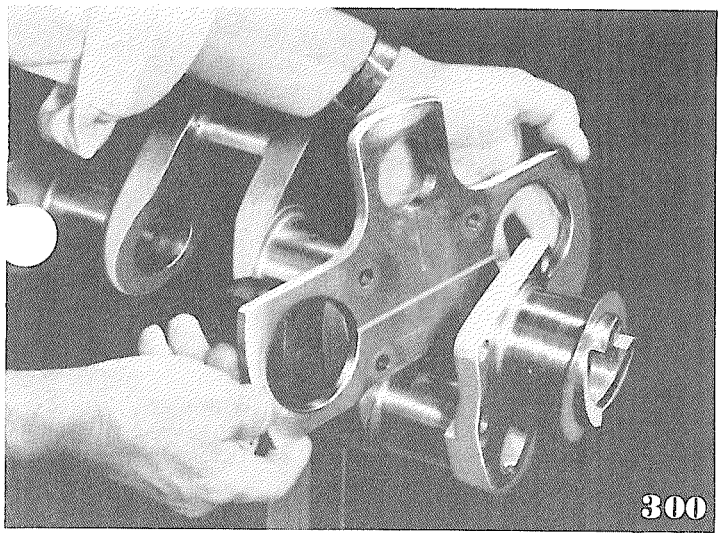
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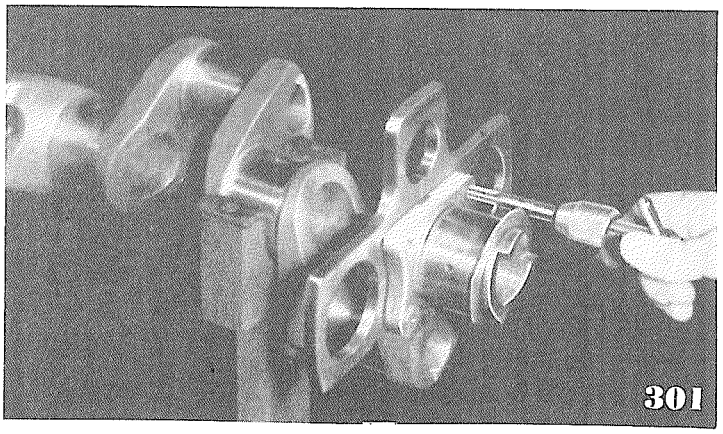
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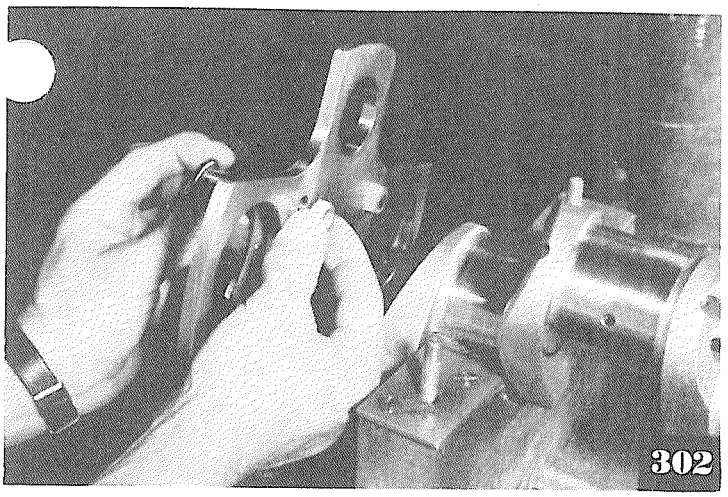
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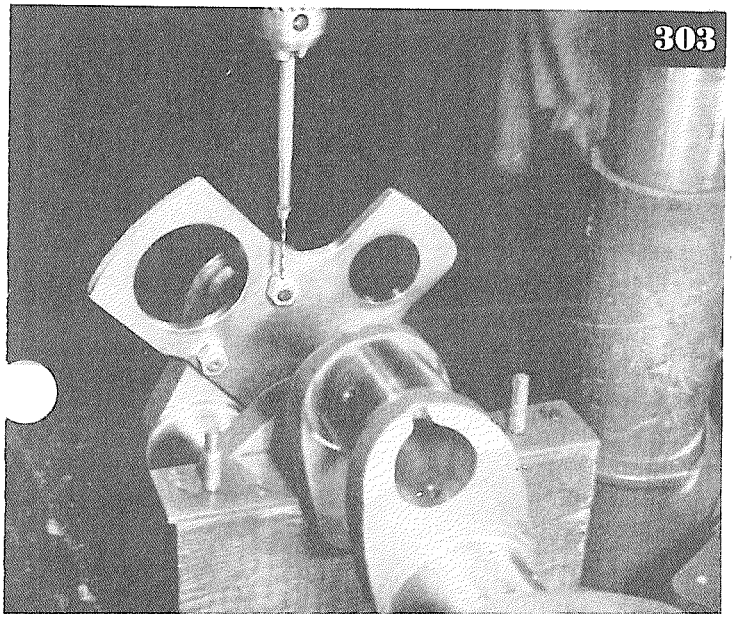
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Crankshaft Damper

Place the crankshaft damper plate against the crankshaft with the grooved side adjacent to the attaching pad on the crankshaft **300**

Clamp the plate to the attaching pad lightly, and line-ream one of the holes to give the proper fit with the new bolt.....**301**

Install the new bolt and nut. (Bolts must be inserted from rear.).....**302**

Ream the hole diagonally opposite the first bolt and install a new bolt and nut. Ream the remaining holes and install new bolts and nuts. Tighten all the nuts with a torque wrench to the torque specified in the Table of Limits.

Using a No. 47 drill, drill a hole through each nut and bolt, making sure that the drill enters the nut in the center of a hexagon face and exactly at right angles to it...**303**

Ream the hole with a No. 5/0 taper reamer so that the large end of the taper pin extend 1/32 of an inch before being driven home. Drive the taper pin down until the large end is 1/64 of an inch below the surface of the nut, and peen the nut over the pin.

Group the front and rear damper weights, rings and spacers according to their proper locations. Place each set with a new bearing in position on the damper plate, and secure with new bolts and nuts. Insert all the bolts from the front.....**304**

Tighten the nuts to the proper torque, using a torque wrench. Drill a hole through nut and bolt, taper-ream and safety with a taper pin as previously described. Check the clearance between damper weights and damper plate to see that they are within the limits specified.

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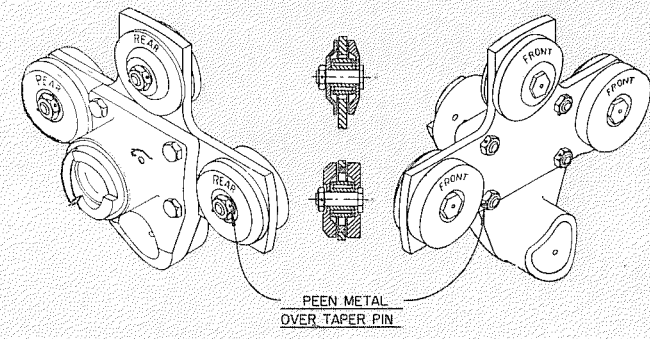

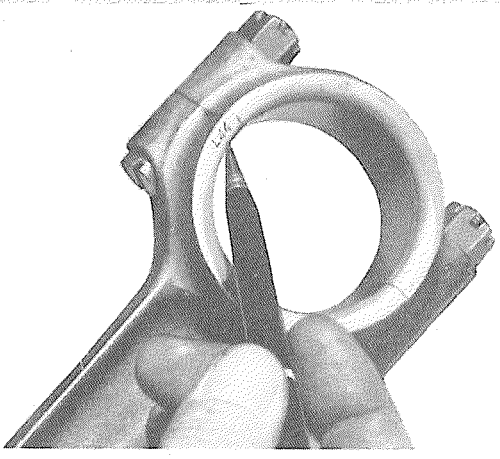

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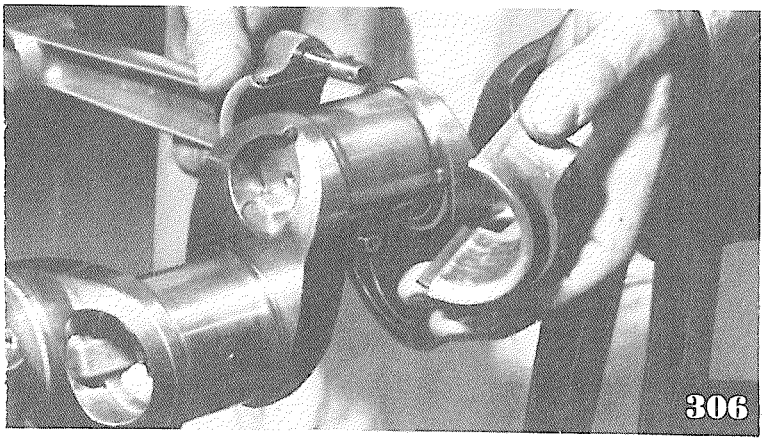

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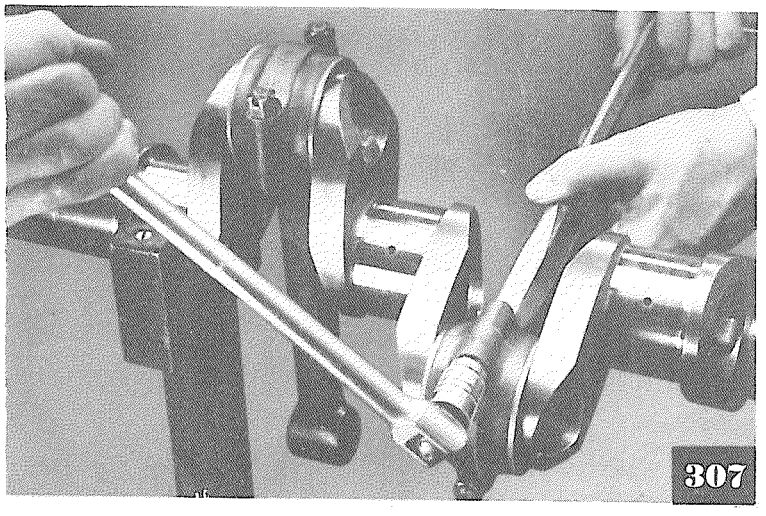

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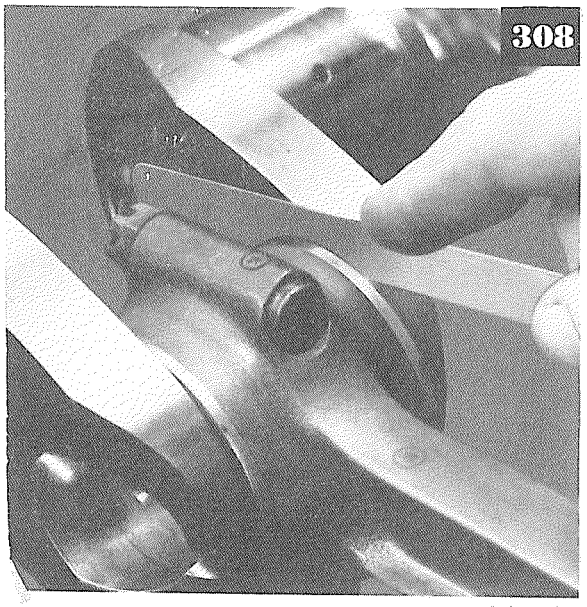

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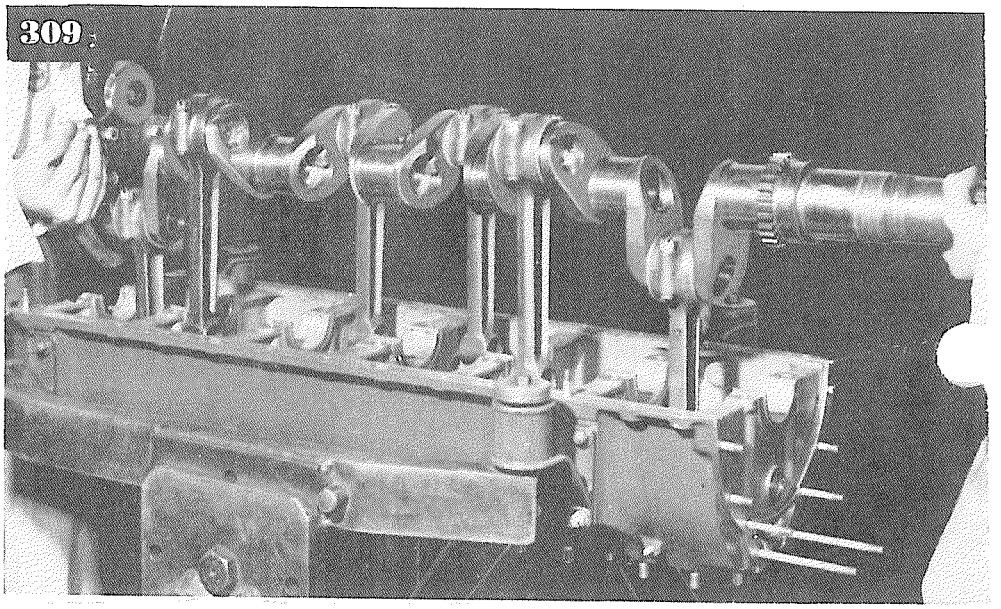


309

Connecting Rods

Place the connecting rod bearings in the connecting rods and in the connecting rod caps. It is important that the bearings be installed with their location numbers toward the rear and on the left or intake side of the engine. **305**

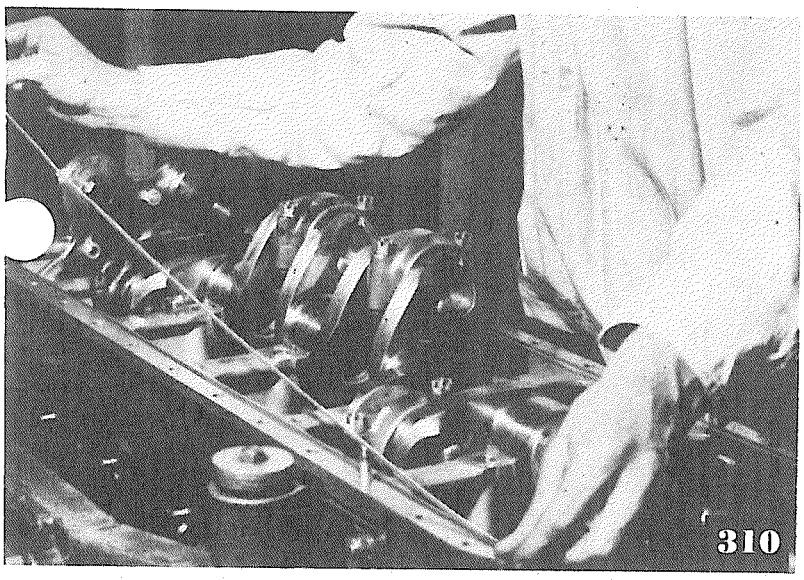
Rotate the crankshaft until the No. 1 crankthrow extends vertically upward and attach the connecting rod and cap. **306**

Put the connecting rod bolts in place and install the nuts, turning them down only enough to hold the connecting rods and bearing caps together. Hold the bolts so that the cotter pin holes are parallel to the crankshaft, using a Screw Driver, AT-193, and tighten the nuts to the required torque, using a Connecting Rod Wrench, AT-192. . . . . **307**

When the proper torque has been attained, the nuts may be further tightened only if it is necessary to align the cotter pin hole with the next slot in the nut. When safetying the nut, new cotter pins must be used. At this point the rod must be checked to make sure that it rotates freely on the crankshaft, and that the side clearances are within those specified in the Table of Limits. **308**

Rotate the shaft as necessary and install the rest of the connecting rods.

Lift the crankshaft and connecting rod assembly from the crankshaft assembly stand with the rods hanging down from the crankpins. Lower the assembly carefully into place in the lower crankcase, guiding the rods through the cylinder openings so that they do not strike the case. **309**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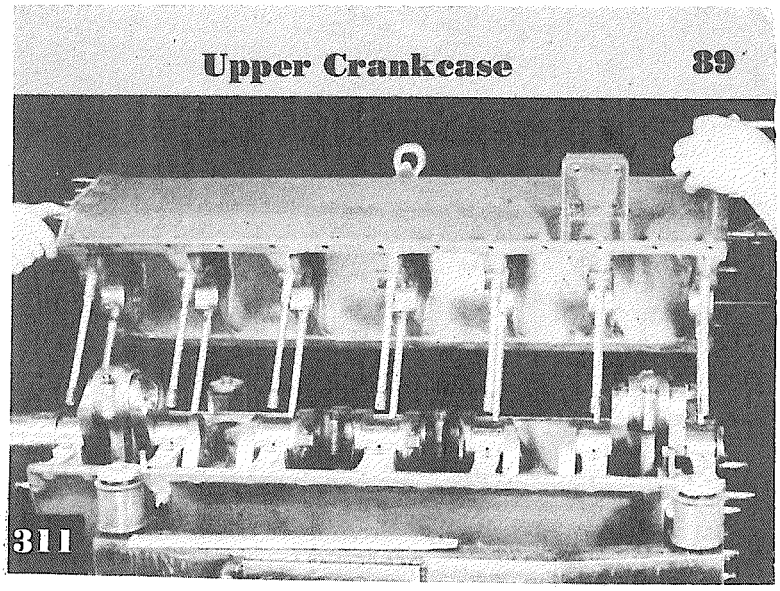
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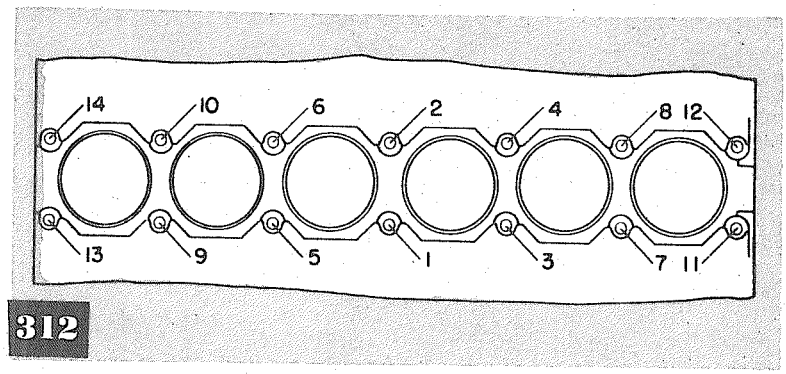


312

Upper Crankcase

Place the upper halves of the main bearings in their proper location and position in the upper half of the main crankcase. Coat the bearings and the bearing seats and fill all the oil passages with lubricating oil.

Inspect the parting surfaces of the upper and lower crankcases to make sure that they are free of nicks, dents, and scratches, and that they are thoroughly clean. Install new rubber oil seals in the grooves of the parting surfaces of the lower half of the main crankcase.....**310**

Place the upper crankcase section in position on the lower crankcase, taking care that the bearings do not drop out while the case is inverted.....**311**

Check the rubber oil seals to make sure that they are properly located as the crankcase is closed. Tighten the nuts on the crankcase flange studs finger tight.

Remove the lock pins on the side of the engine assembly stand and invert the engine. The engine stand should be immediately locked before proceeding with the assembly of the engine.

Install the fourteen crankcase main bearing studs and washers, turning them down lightly. Tighten the nuts to their proper torque, starting with the center nuts and working diagonally across the engine toward the front and rear.....**312**

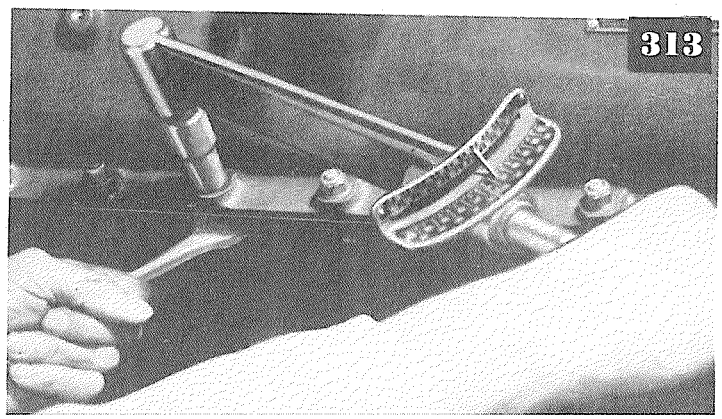
Safety all nuts with cotter pins.

Invert the engine, returning it to its normal position.

Tighten the crankcase flange nuts to their proper torque, starting with the center nuts and working diagonally across the engine toward the front and rear.....**313**

Rotate the crankshaft to check for freedom of movement. When turning the shaft, be careful not to allow the connecting rods to strike the edges of the cylinder pads, causing possible damage.

Place the lifting eye in its proper position on the crankcase, and install and tighten the two 5/16 inch nuts to their proper torque **314**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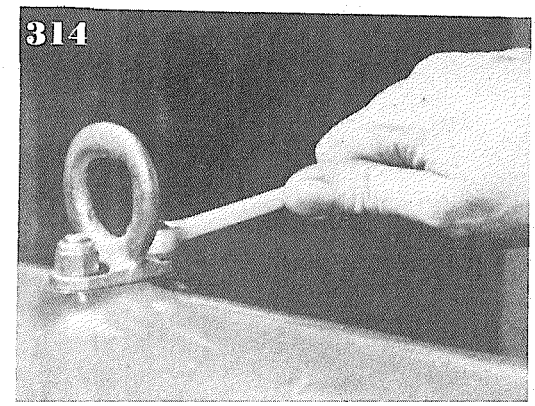
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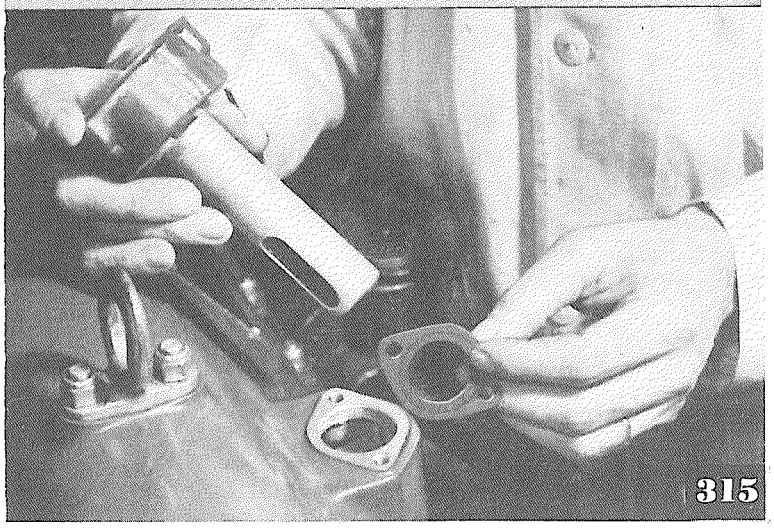
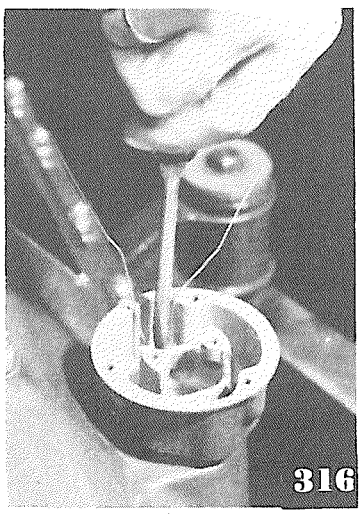

315

Place a new gasket on the breather body pad that comes in contact with the upper crankcase, ...315
and secure the breather body in the crankcase, using two cap screws and washers. 316
Using two capscrews and washers, fasten the breather inner cover to the breather body 317
Place a new gasket in its proper position on the parting surface and fasten the outer breather cover to the breather body, using three capscrews and washers. 318

Ends of the rubber oil seals that extend beyond the edges of the parting flange of the main crankcase, should be cut off at this time.....319

Install new magneto oil retainers in their proper location in the upper crankcase, using a Drift, AT-203.....320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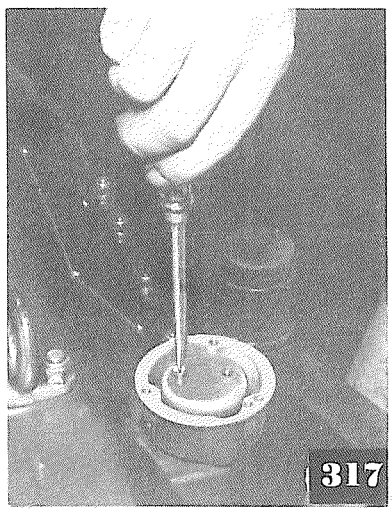
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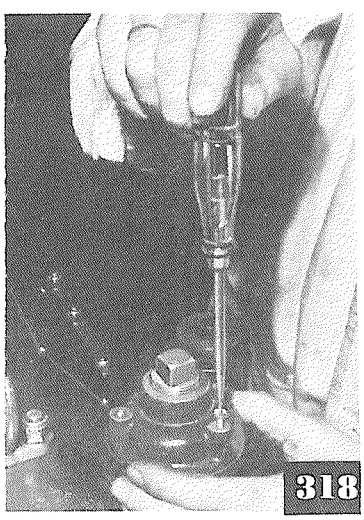
Accessory Drive Shaft

Place the accessory drive shaft, front end up, in a vise equipped with copper jaws, being careful to clamp the shaft between the journals. Using a Drift, AT-205, drive a new cup plug into the front end of the accessory drive shaft.....321
Line up the cotter pin hole in the front end of the shaft with the cotter pin hole in the thrust plug, and drive the plug in the shaft, using a composition mallet.....322
Invert the shaft in the vise and install a new cup plug in the rear, using a Drift, AT-206.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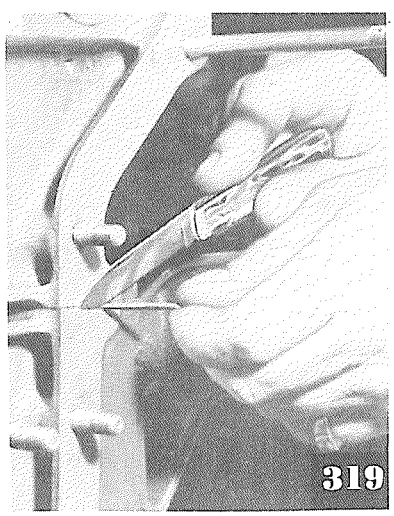
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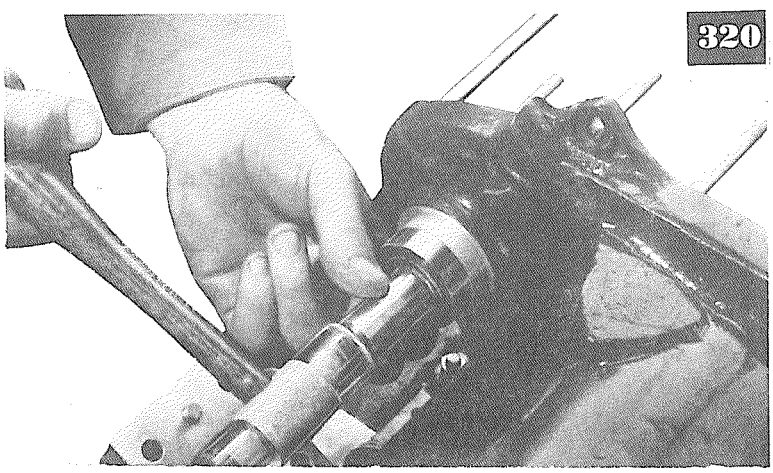
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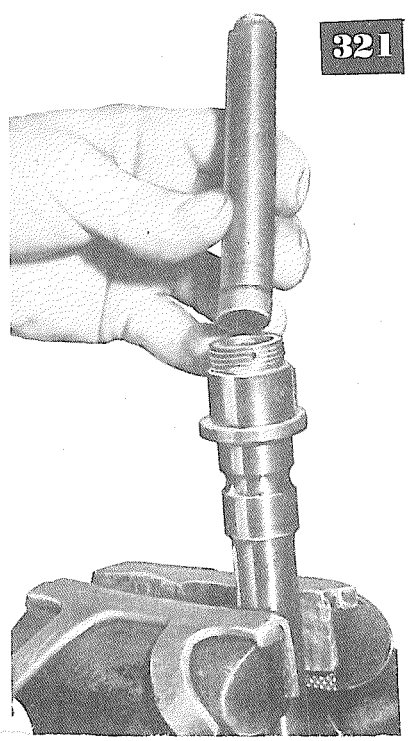
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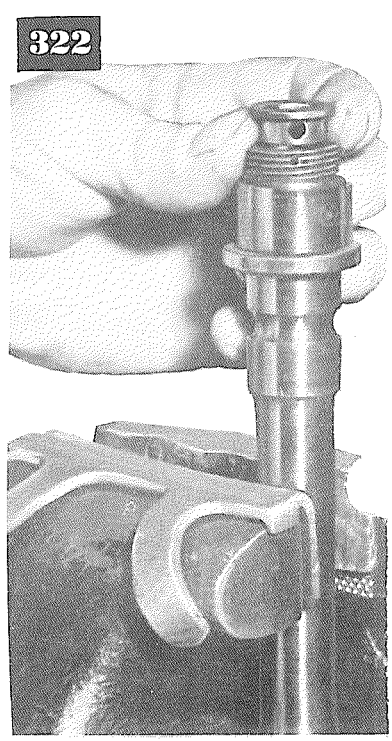
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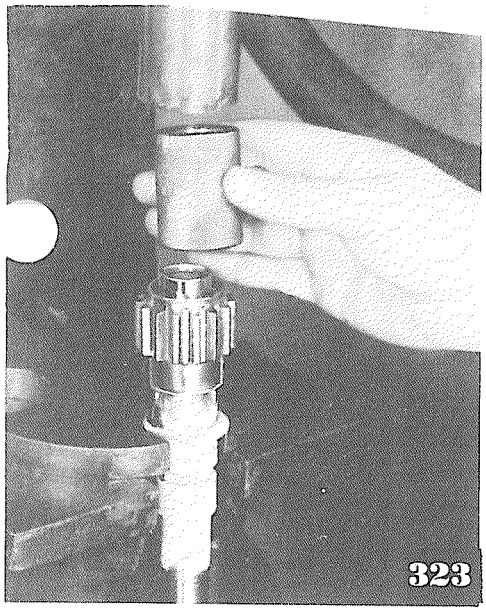
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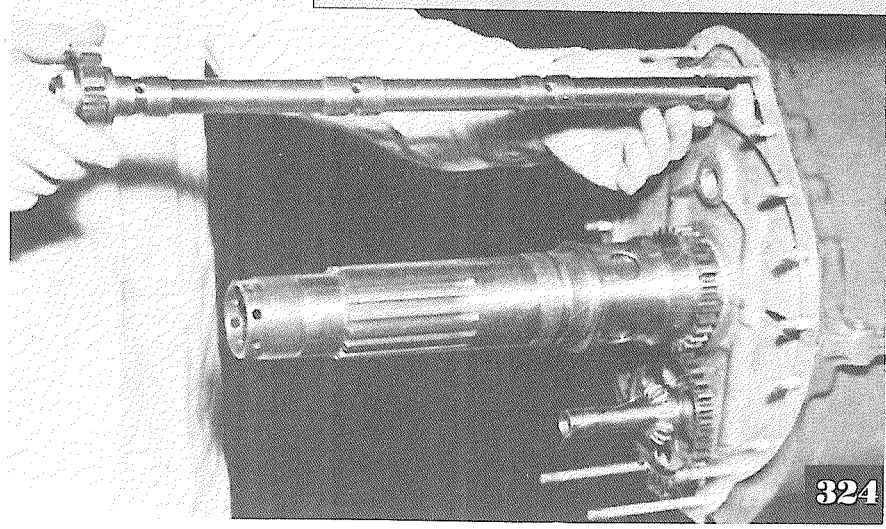
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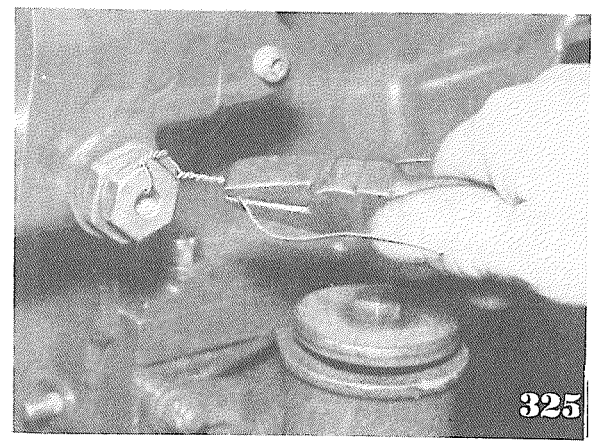
Install a new key in the accessory drive shaft keyway. Where it is necessary, the key may be stoned slightly to insure a proper fit. Place the accessory drive front gear in a pan of oil and heat it to 116° C. (240° F.) Remove the gear from the oil and press the gear on the shaft. **323**

Coat the shaft and gear assembly with lubricating oil, making sure to fill all oil pockets, and slide the assembly into position from the front of the crankcase..**324** When installing the accessory drive shaft, care must be taken not to allow the edges of the journals to strike and damage the bearing surfaces in the upper crankcase. Rotate the shaft by hand, to be sure that it is free to turn without binding or roughness.

REAR CRANKCASE ASSEMBLY

Coat the threads of the oil passage plugs with a thread lubricant and install the plugs in their proper locations. Place a new copper gasket on the pressure oil inlet strainer and thread the strainer into position at the oil inlet in the rear crankcase. Put a new copper gasket on the pressure oil inlet screen magnet, and install the magnet in the inlet screen. Safety the screen and magnet with wire.....**325**

Place the retaining spring over the oil relief strainer and place them in their proper place in the rear crankcase. Place a new copper gasket on the flange of the strainer cover and install the cover.....**326** Place a new copper gasket on the strainer cover plug and insert the plug in the cover. Safety the cover and plug with wire..**327**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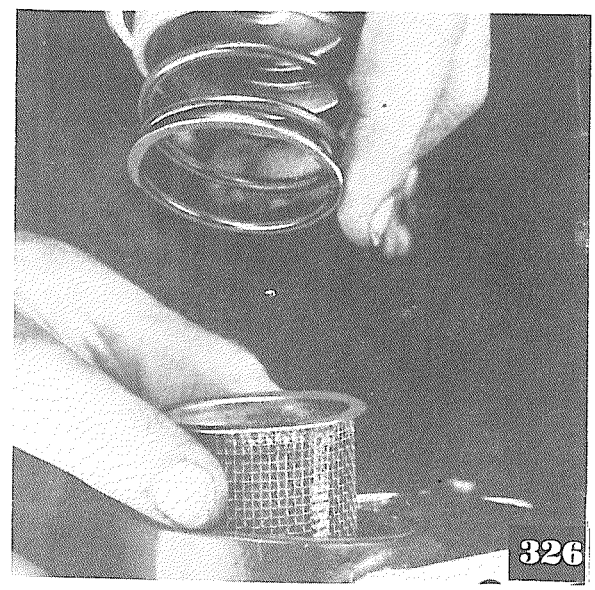
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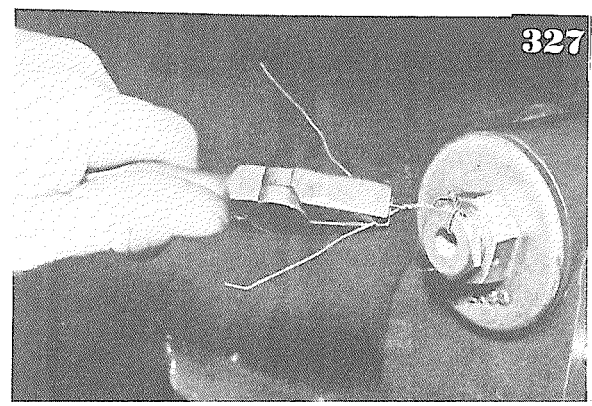
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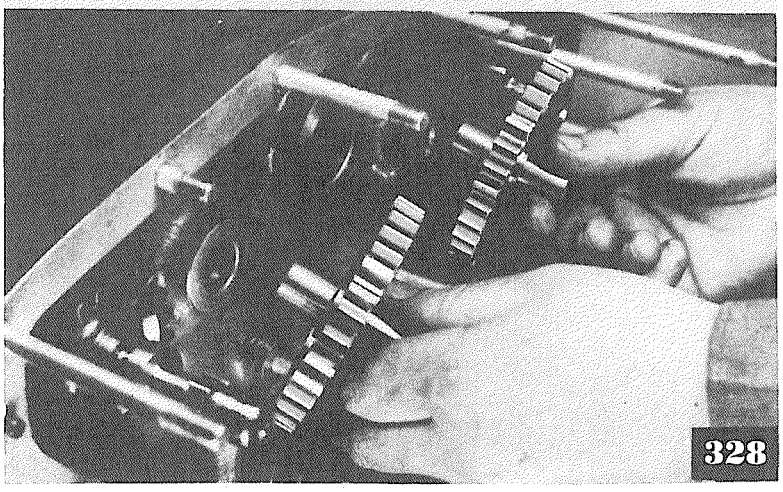
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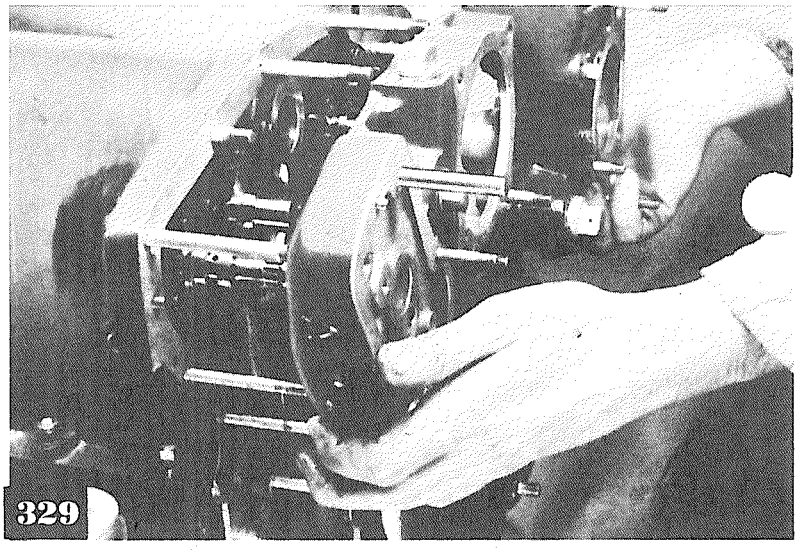
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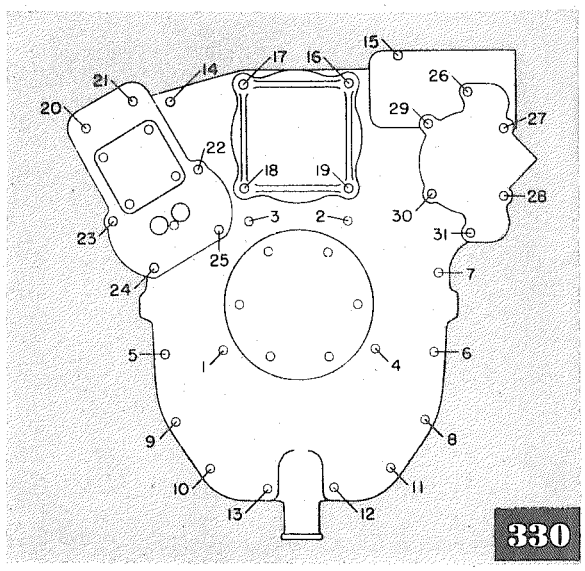
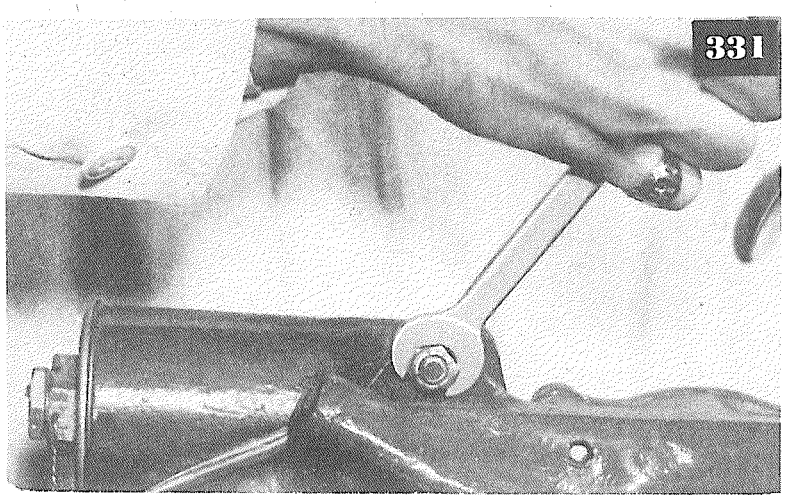


330

Coat the two rear idler gears, the right magneto drive gear and the left magneto and vacuum pump drive gear with oil, and place them in their proper positions in the rear crankcase.....**328**

Stone out any slight nicks or scratches that might be present on the parting surfaces of the rear crankcase or the main crankcase. Thoroughly clean, and then apply sealing compound to the parting surfaces.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Mount the rear crankcase with the gears installed, on the main crankcase.....**329**

Install the attaching nuts and tighten them finger tight. Bring the nuts to the proper tightening torque, starting with the nut located at the lower left of the starter pad, and working back and forth across the engine **330**

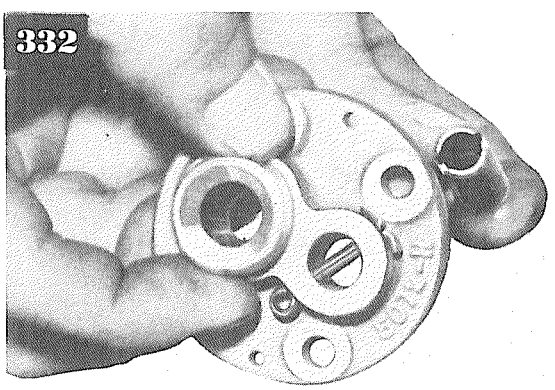
One of the attaching nuts is located on the front side of the upper crankcase flange **331**

Pressure Oil Pump Assembly

Secure the pressure oil pump idler gear shaft in the pump cover with a cotter pin **332**

Insert the pressure oil pump drive shaft into its proper position in the cover..**333**

Place the idler gear and the drive gear in position on their corresponding shafts. In-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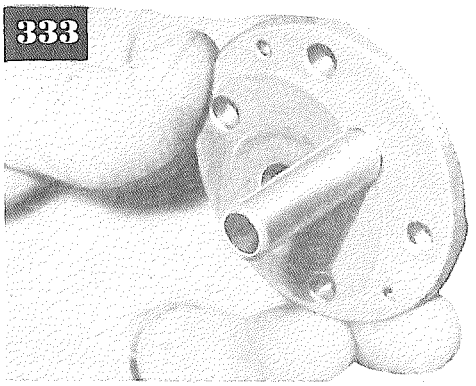
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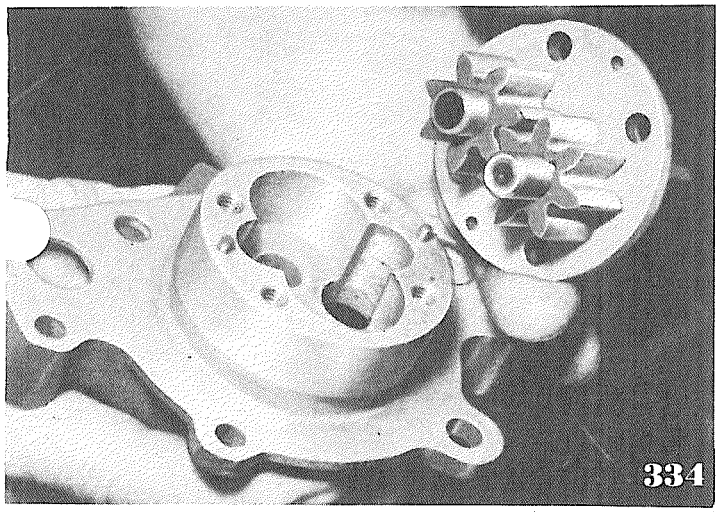
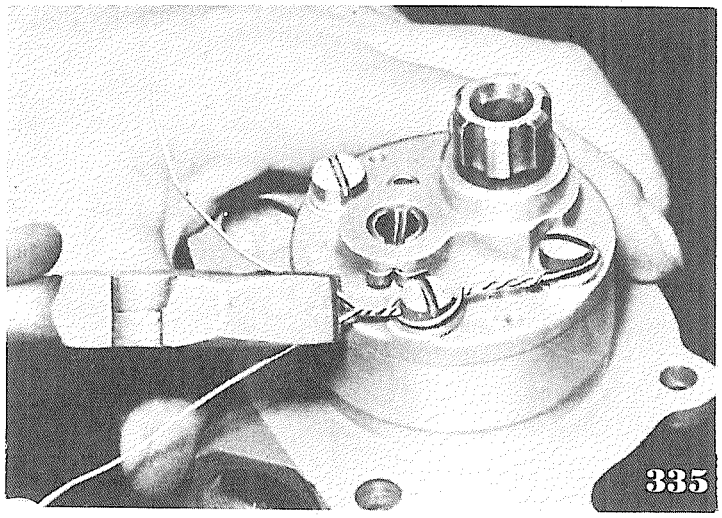
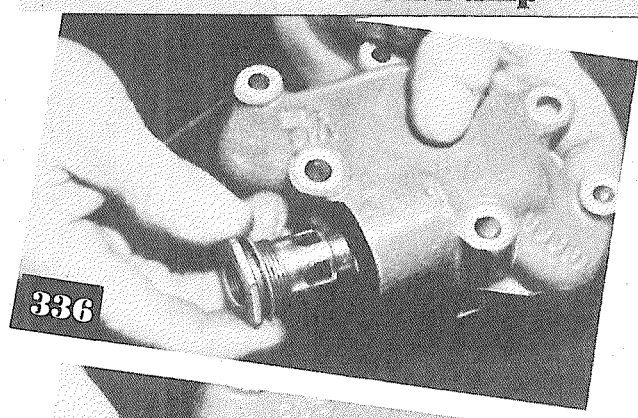


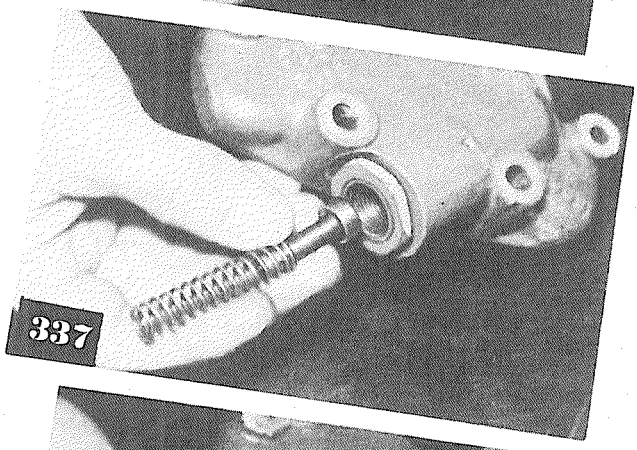


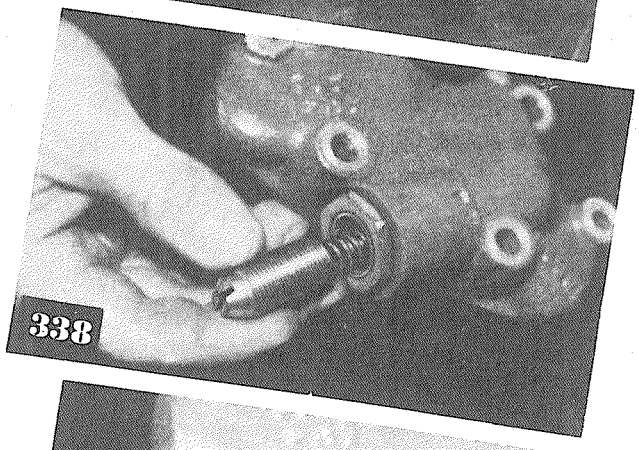
stall the assembled parts of the pump in the housing 334
and secure the cover in place using four capscrews and washers. After the capscrews have been tightened to their proper torque, they should be safetied with lockwire 335

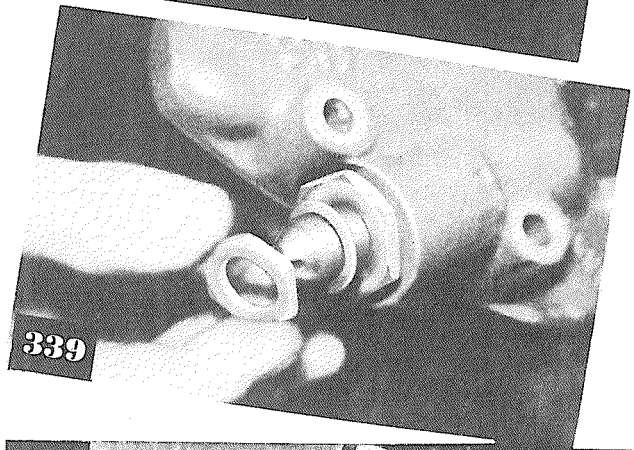
Place the pressure oil relief valve seat in the pump housing using a new copper gasket 336
Insert the relief valve in its proper position in the seat and slip the relief valve spring over the stem of the valve.....337
Secure the valve and spring in position by installing the adjusting screw.....338
Slide a new copper gasket over the adjusting screw and turn on the locknut. Place another new copper gasket on the locknut and install the protecting cap.....339

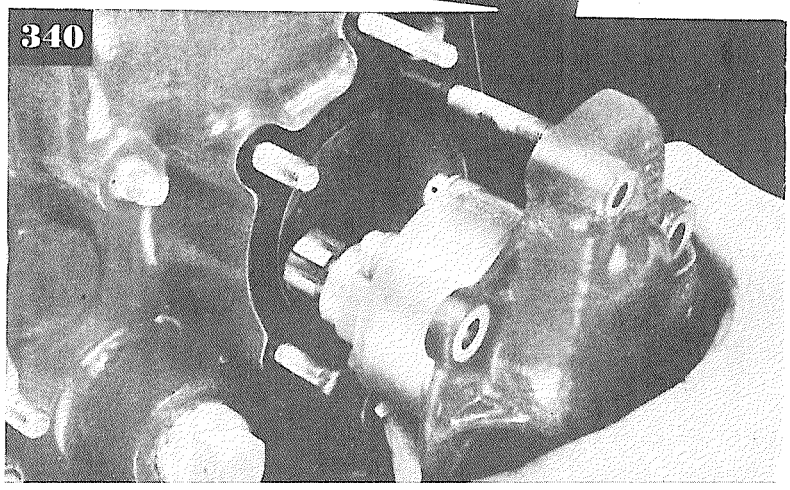
Place a gasket on the parting surface of the pressure oil pump housing. Pour oil into the pump inlet while turning the gears until the pump is completely filled. Then install the complete assembly on the rear crankcase 340

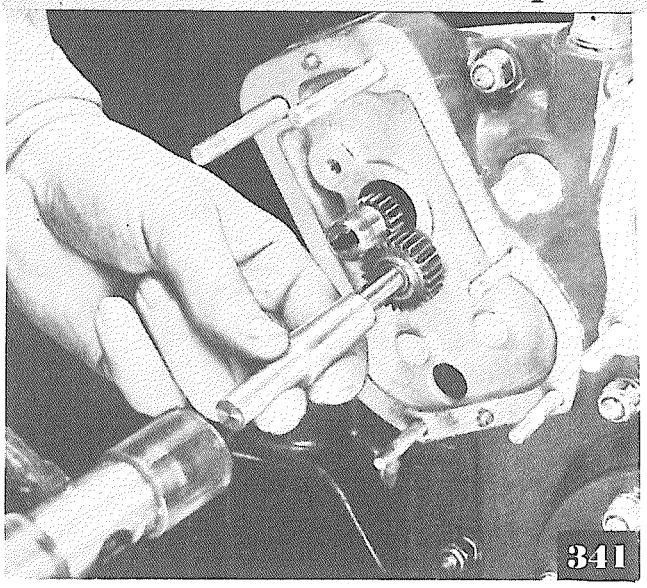








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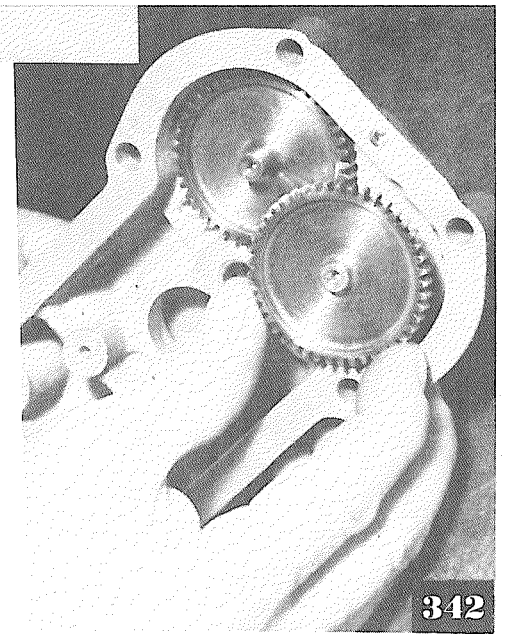
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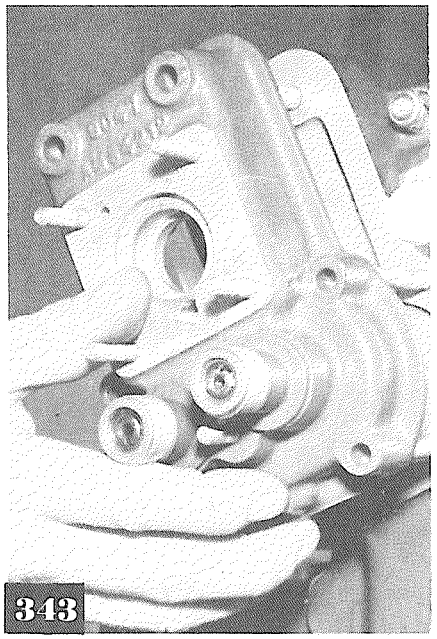
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When installing the assembly, make sure that the splines on the oil pump drive shaft are in mesh with the internal splines of the right magneto gear. The pressure oil pump assembly may now be fastened to the rear crankcase by tightening the retaining nuts to the proper torque.

Vacuum Pump and Tachometer Drive Housing Assembly

Engage the tachometer drive idler gear with the mating teeth of the magneto and vacuum pump gear located in the rear crankcase. Holding the gear in its proper position, install the idler gear shaft using a composition mallet if necessary....**341**

Place the long and short tachometer gears in the housing.....**342**

Apply sealing compound to the parting surface of the housing and install the housing on the rear crankcase.....**343**

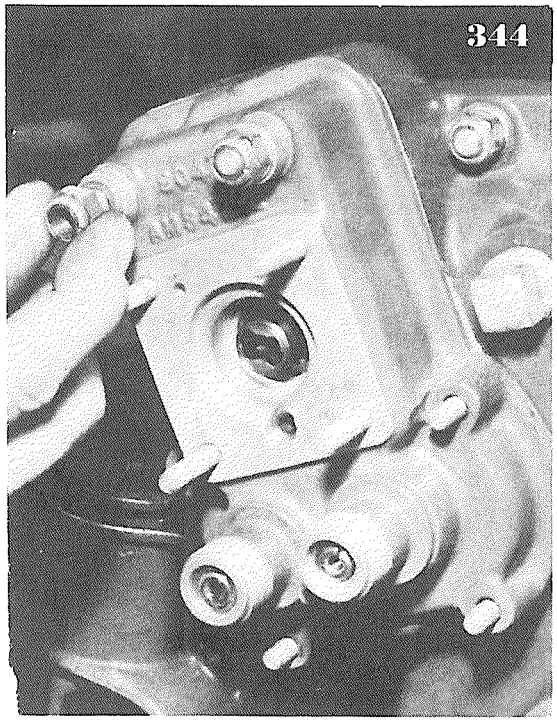
Place a spacer and a washer on each of the two top studs and fasten into place with two 5/16 inch self locking nuts.....**344**

Put washers on the four lower studs and lock into place with ¼ inch self locking nuts.

These nuts should now be tightened to the proper torque in the order shown in **345**

Insert the vacuum pump drive oil retainer, using an Oil Retainer Drift, AT-196 .....**346**

The vacuum pump cover and gasket should now be installed and secured with four ¼ inch washers and self locking nuts.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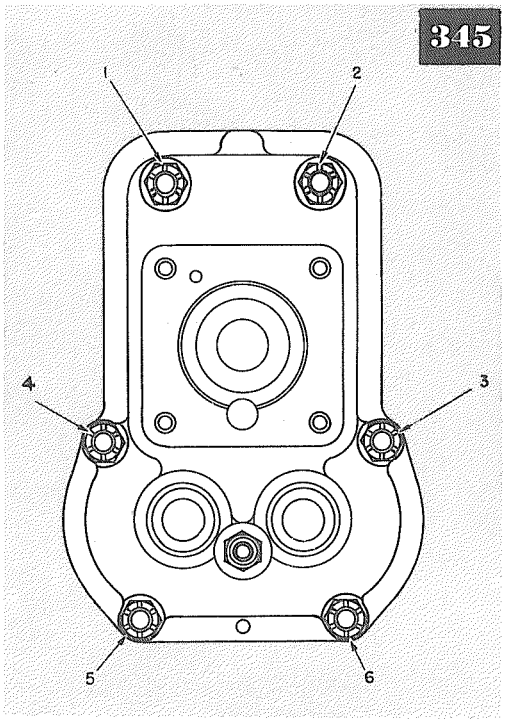

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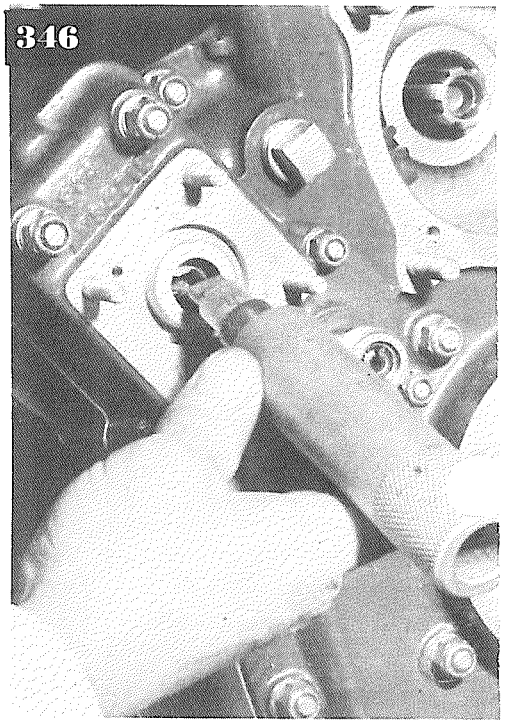
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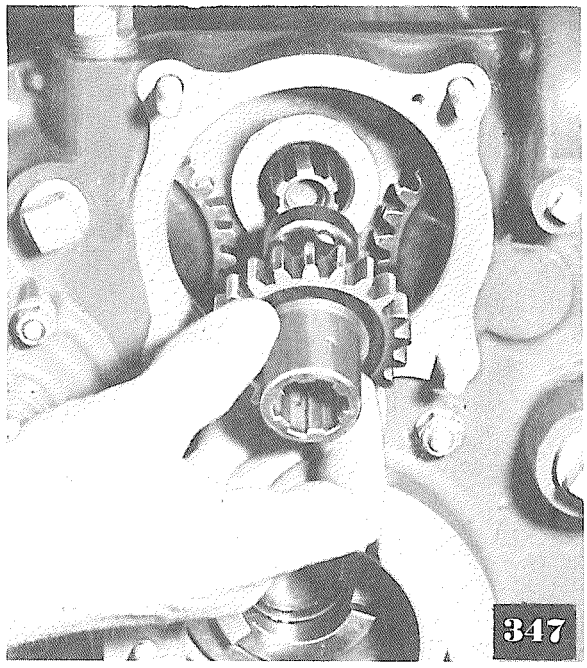
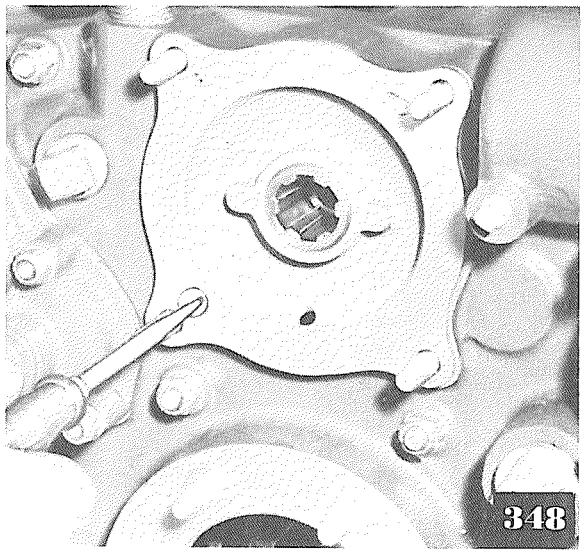
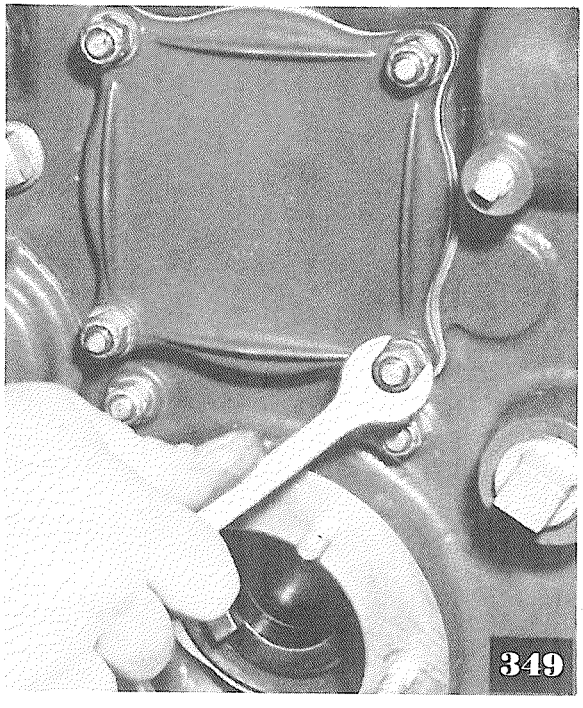
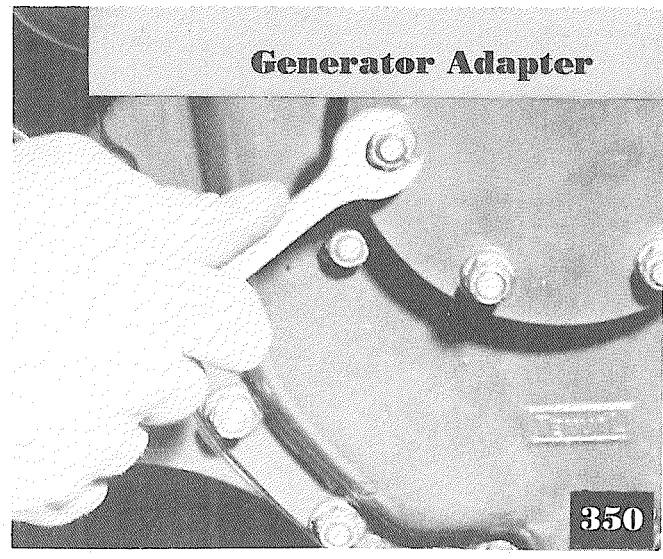
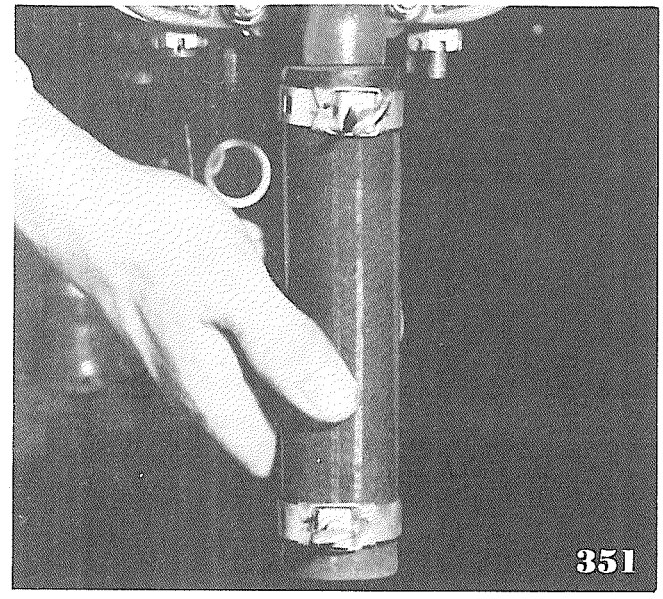










Generator Adapter and Cover Plate

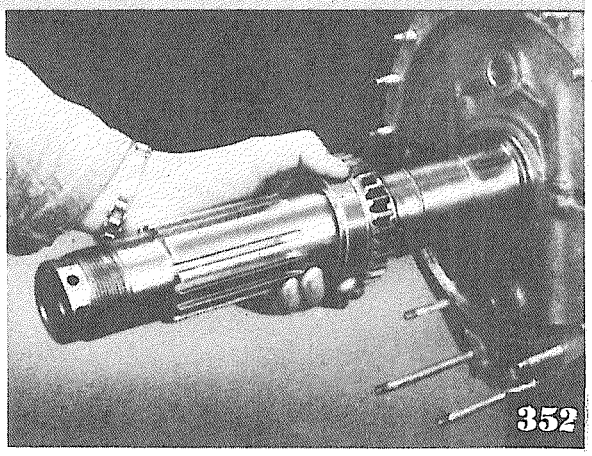
Install the accessory drive shaft rear gear on the rear end of the accessory drive shaft **347**

Stone out any slight nicks or scratches that might be present on the parting surfaces of the generator adapter. Coat the surface with sealing compound and install it on the rear crankcase, using two flat head screws **348**

Make sure that the heads of the screws are seated in the countersunk holes in the generator adapter. Fasten the generator cover plate and gasket, using four 5/16 inch washers and self locking nuts.....**349**

The starter cover plate and gasket should now be installed using six 5/16 inch washers and self locking nuts.....**350**

Place two hose clamps in their proper position on a new rear oil drain hose and install the hose on the rear crankcase.**351**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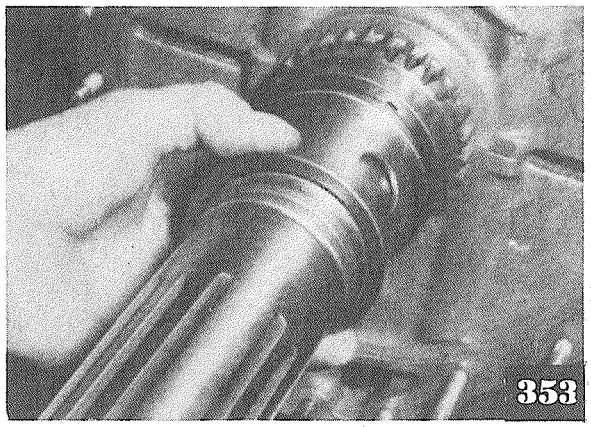
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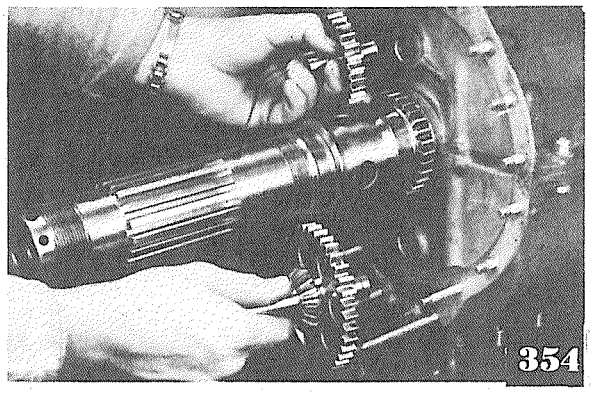
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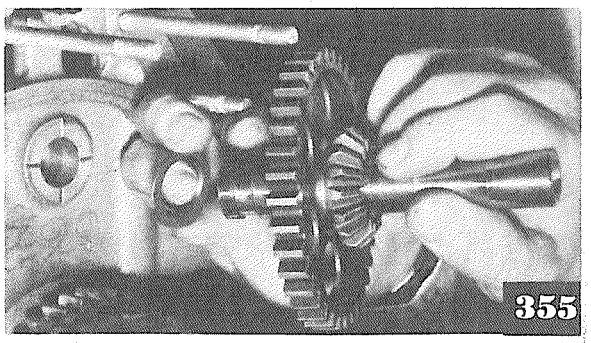
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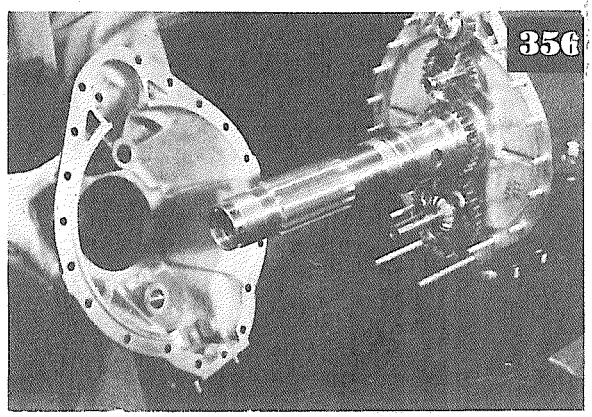
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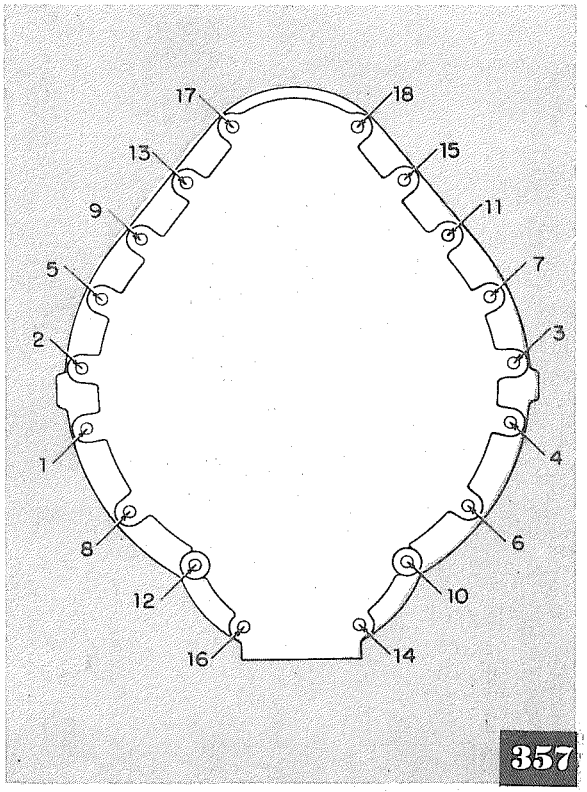

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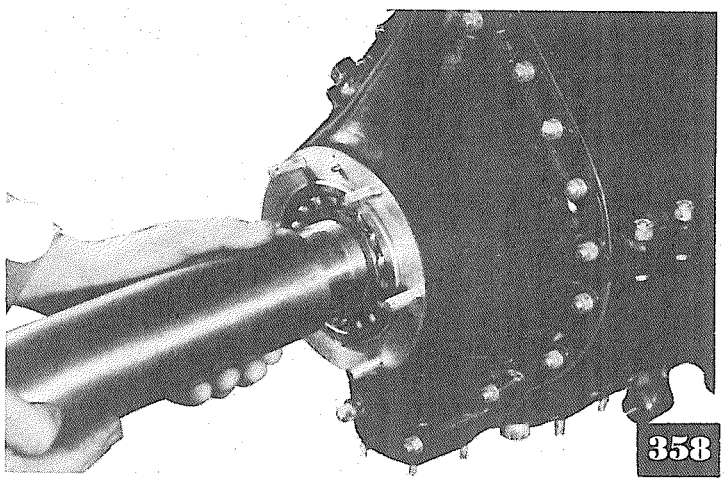
FRONT CRANKCASE ASSEMBLY

Install the crankshaft gear key in its keyway. Slide the crankshaft gear into position on the crankshaft, making sure that it rests flush against the flange on the shaft. . . **352** then slide the spacer against the gear. **353**

Coat the upper front idler gear and the lower front idler bevel and spur gear assembly with oil and install in their proper positions in the main crankcase. . . . . **354** When installing the lower idler gear assembly, it is important to see that a thrust washer of the proper thickness be inserted between the assembly and the main crankcase, and that the beveled side of the washer is toward the gear assembly. **355**

Coat the parting surface of the front crankcase with sealing compound and install it on the main crankcase. . . . . **356** making sure that the shafts of the gears engage with their respective bearings. Then install the attaching nuts finger tight. When all the nuts are in place, they should be tightened to the proper torque, working diagonally across the engine. **357**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Thrust Bearing and Cover

Using a Driver, AT-139, install the thrust bearing on the crankshaft.....**358**
When installing the bearing, make sure that the lettered side is toward the front of the engine and that the bearing rests flush against the crankshaft spacer.

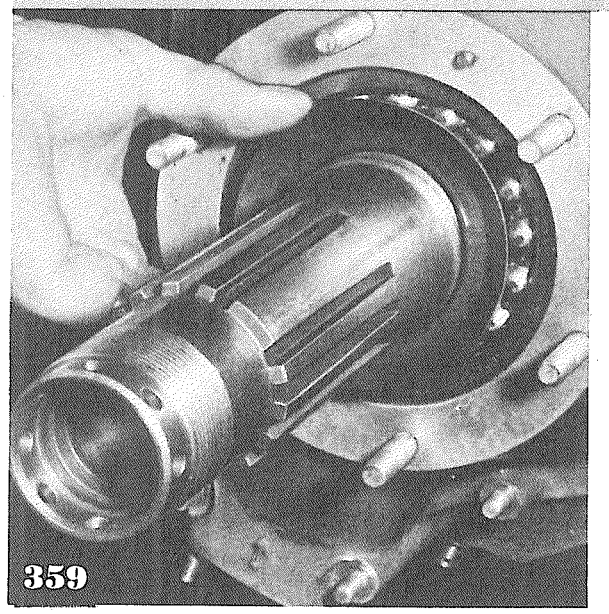
Place the oil slinger in its proper position on the shoulder of the crankshaft so that the raised outer edge of the slinger points forward.....**359**
Coat the front crankcase cover and the laminated shim with sealing compound, and install the cover and shim on the front crankcase so that the oil relief is at the bottom of the cover **360**
When installing the cover, care must be taken not to dislodge the crankshaft oil slinger from its proper position. Install and tighten the attaching nuts to their proper torque in the order shown in.....**361**
After the nuts have been tightened, they should be safetied with lockwire. Install the thrust nut until it is finger tight. It is not advisable to try to tighten the nut all the way at this time, as there is no way to prevent the crankshaft from rotating.

Remove the retaining pins from the side of the engine assembly stand and invert the engine. As soon as the engine has been inverted, the cradle of the assembly stand must be locked by re-inserting the retaining pins.

CYLINDERS AND PISTONS

Assembly of Pistons

A complete new set of piston rings must be installed at each overhaul. It is important that all piston rings be installed in their proper locations. In the groove nearest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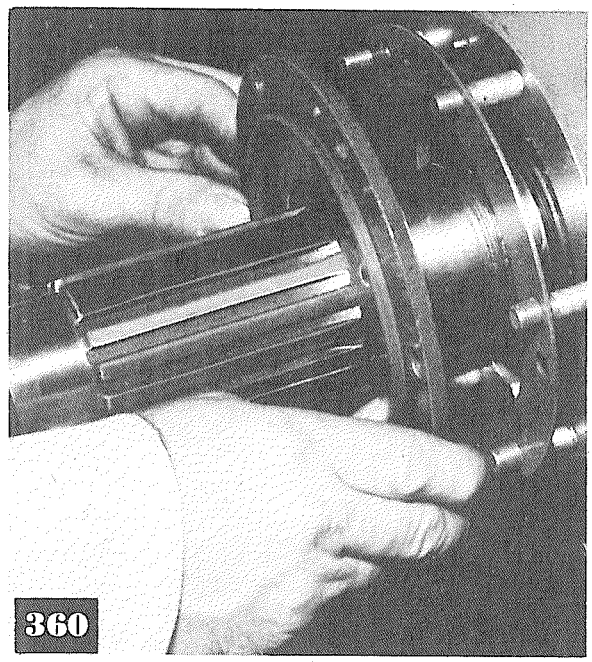
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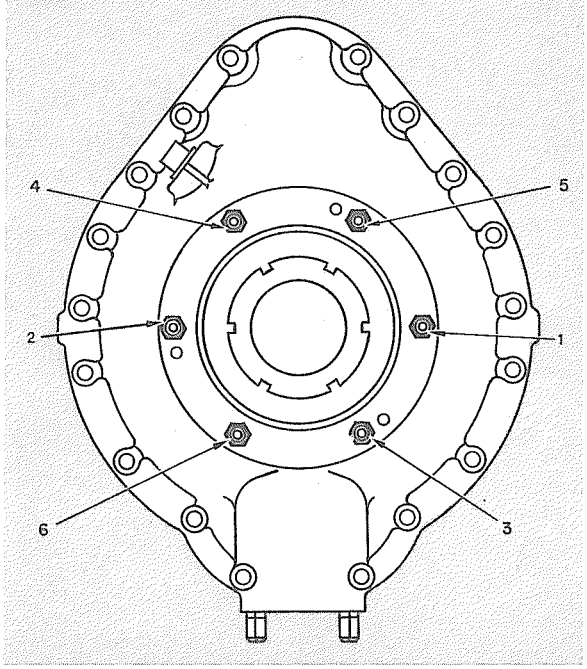

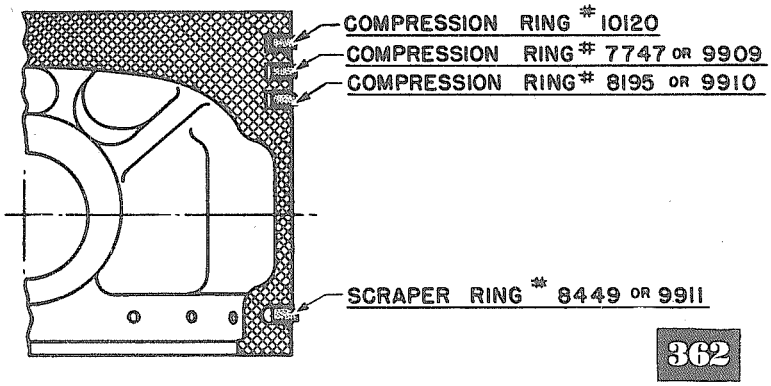

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the head, a straight compression ring is installed. In the next two grooves, tapered compression rings are used. The oil scraper ring is located in the single groove below the piston pin boss.....362

If oversize cylinders are used, oversize pistons and rings must also be used to maintain proper clearances.

Before placing the piston rings on the piston, they should be checked for end clearance by placing each ring in its respective cylinder, parallel to the mounting flange, and measuring the end gap with a feeler gage.....363

Install the piston rings on the pistons with the aid of a Piston Ring Expander, AT-122 364

Never expand the rings any more than is necessary to clear the lands on the piston. It is very important to see that the tops of the rings are toward the head of the piston. As an aid, the word "top" has been etched on the top surface of each ring, near the gap 365

After all the rings have been installed on the pistons, each ring should be checked all the way around its groove for side clearance with a feeler gage.....366

Install one new circlip in each piston, making sure it is properly seated in its groove 367

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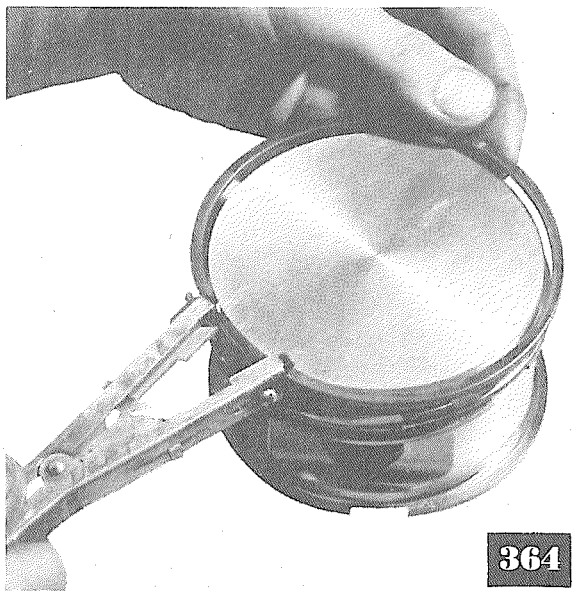
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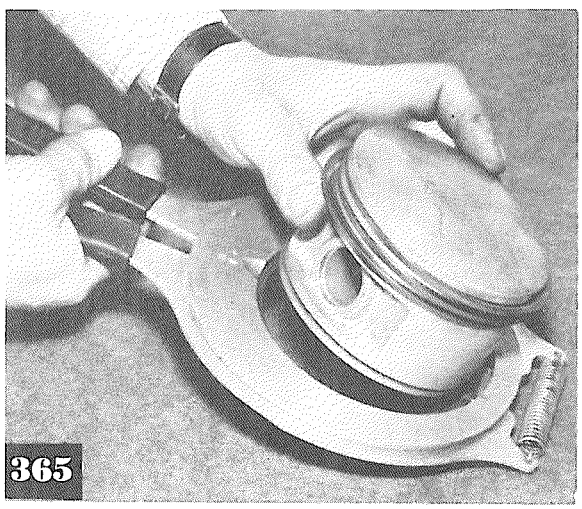
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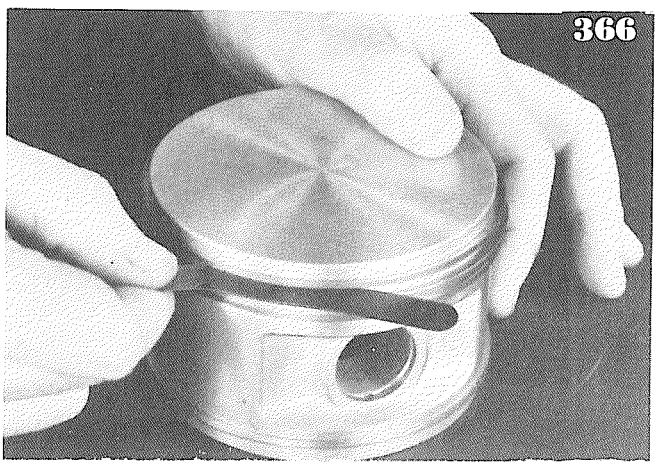
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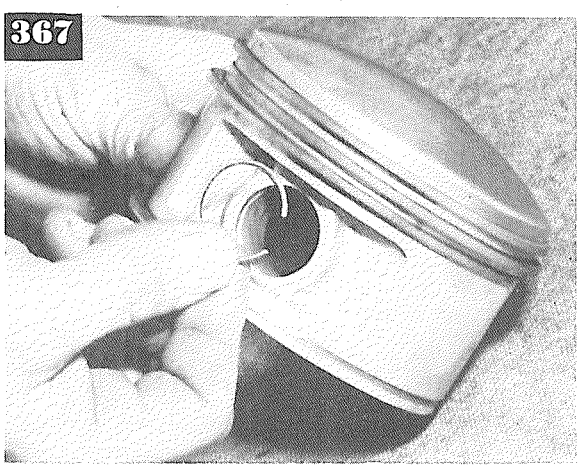
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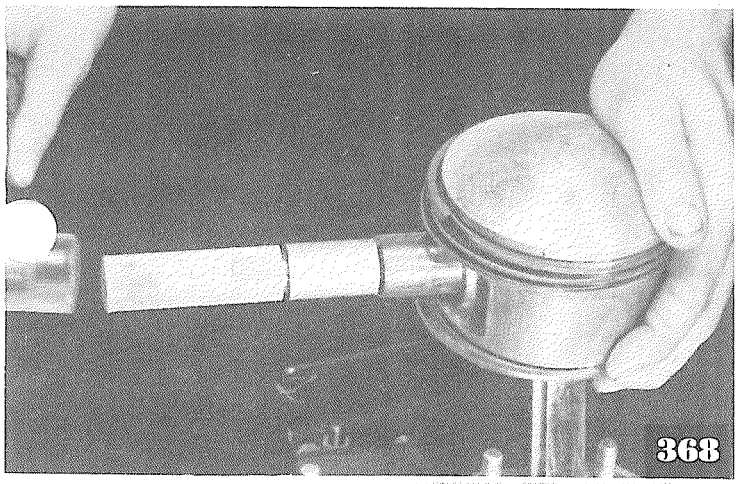
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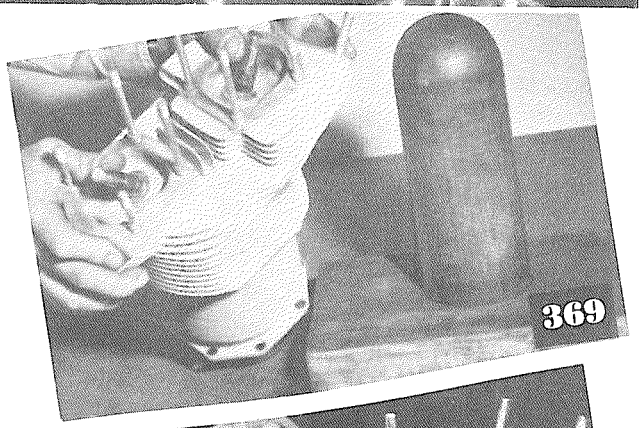
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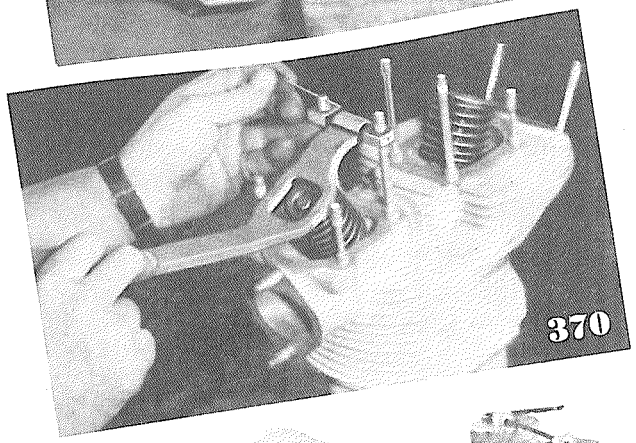
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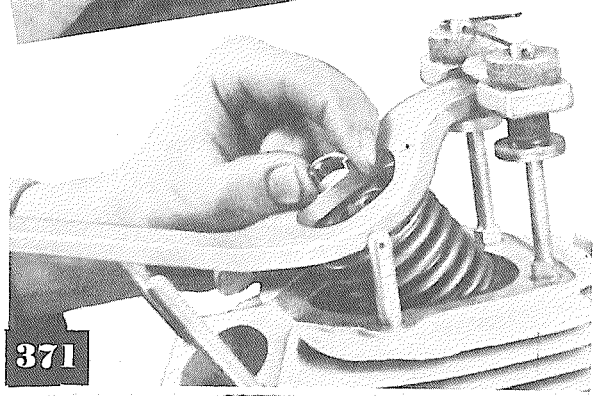
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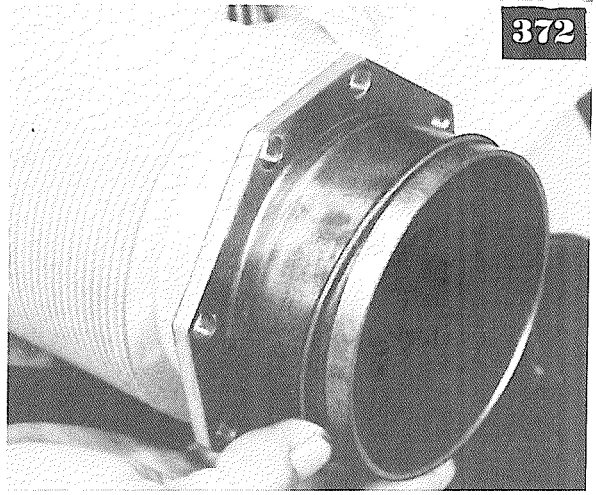
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Installation of Pistons

Place the Timing Indicator, AT-166, on the propeller end of the crankshaft and use it to rotate the crankshaft, to facilitate placing the pistons on the connecting rods.

Rotate the crankshaft until the number one and number six connecting rods are fully extended at the top of their stroke. When rotating the shaft, care must be taken not to allow the connecting rods to strike and damage the edge of the cylinder holes.

Hold the piston in place on the number one connecting rod. Slide the piston pin into position from the side of the piston that is without the circlip. If the piston pin does not slide in readily, it may be tapped into position with the aid of a Drift, AT-142. During this operation the piston must be firmly held, otherwise the connecting rod may be damaged. **368**

The second circlip should now be installed, making sure that it is properly seated in its groove.

The number six piston should now be installed. After this, the crankshaft should be rotated as necessary to facilitate installation of the remaining pistons.

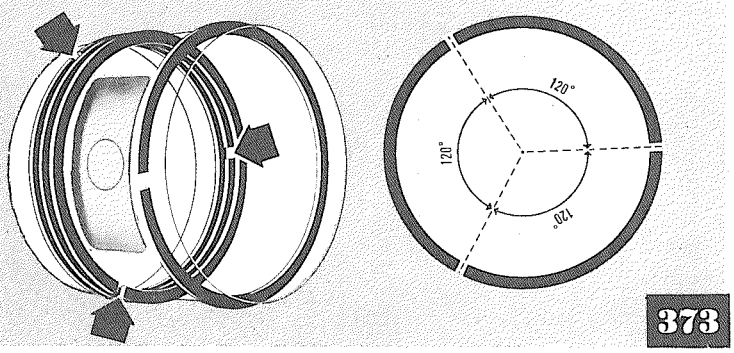
Assembly of Cylinders

Place the intake and exhaust valves in their respective guides and, holding the valves by the stems to keep them in the closed position, place the cylinder over the Cylinder Assembly Block, AT-215. . . . **369**

Slide the upper valve spring washer, the inner and outer valve springs, and the lower valve spring washer into position over the valve stem. Fasten the Valve Spring Compressor, AT-14 to the two large cylinder head studs. **370**

Compress the valve springs to a point below the valve lock groove on the valve stem. Seat the split valve locks in position on the valve stem, and secure them by slowly releasing the pressure on the valve springs. Install the other set of valve springs in the same way. **371**

Lift the cylinder off the assembly block and install the rubber oil seal on the cylinder skirt, making sure that it rests flush against the cylinder flange. **372**



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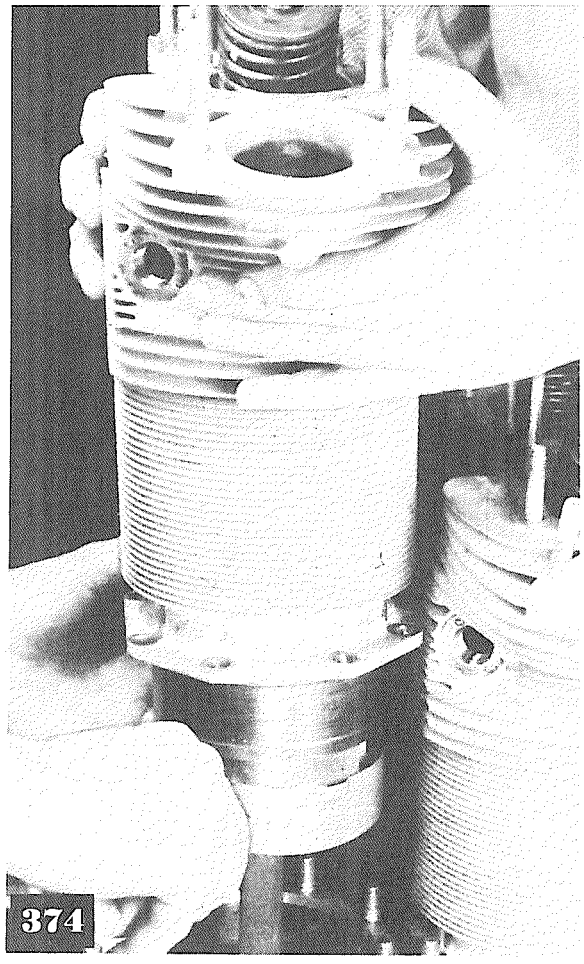
Installation of Cylinders

Rotate the crankshaft so that the number three and number four pistons are at their top center position. Coat the cylinder bores, pistons, piston rings, and piston ring grooves with oil. Set the piston rings so that their gaps are staggered 120 degrees apart **373**

Using a Piston Ring Compressor, AT-133, compress the top three rings of the number three piston on their grooves.....**374** and slide the cylinder over them. Compress the bottom ring and slide the cylinder over it. Then remove the piston ring compressor and slide the cylinder into place against the mounting pad. Place the cylinder attaching nuts on the studs and tighten fully; then back off the nuts ½ turn.

Install number four cylinder; then rotate the crankshaft as necessary and install the number two and number five, and the number one and number six cylinders in their proper positions in the order listed.

Install the Cylinder Aligning Bar, AT-90, on the intake ports of the numbers one, two and three cylinders, and tighten securely. Then tighten the cylinder attaching nuts to their proper torque with the aid of a Wrench, AT-158.....**375**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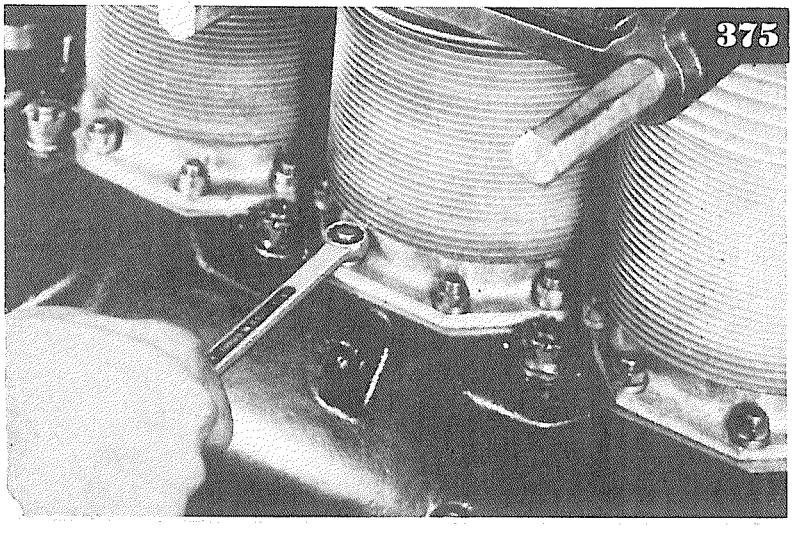
Release the nuts holding the bar and then try to insert a .0015 feeler gage between the bar and each port while holding the bar against the ports by hand.....**376** When the cylinders are properly aligned safety the cylinder hold down nuts by installing locknuts. Cylinders numbers four, five, and six are aligned and secured by observing the same procedure.

As a protective measure, dummy plugs should be inserted in the spark plug openings on the cylinder.

The timing indicator should now be removed from the propeller end of the crankshaft.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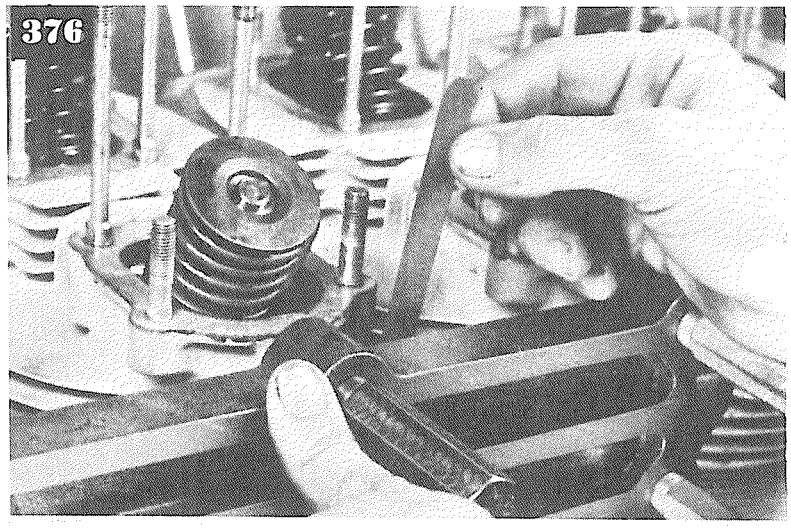
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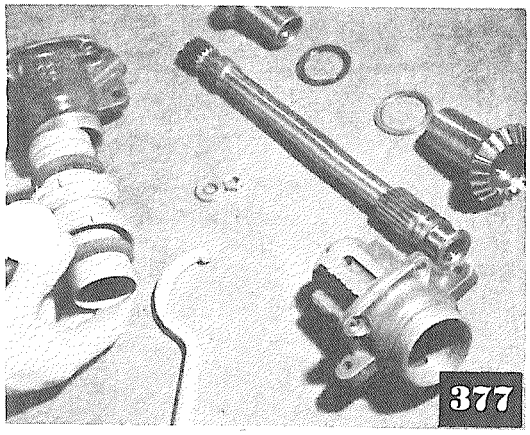
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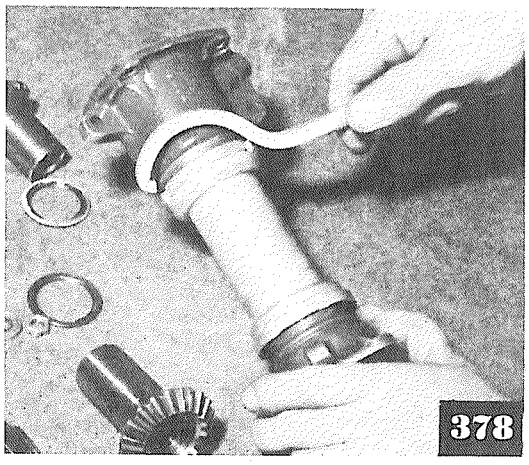
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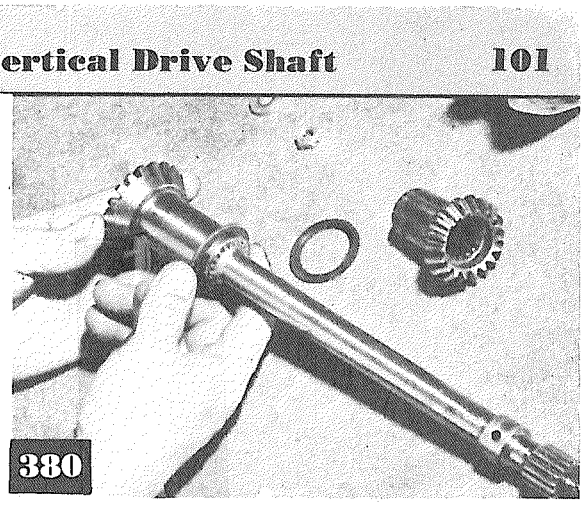
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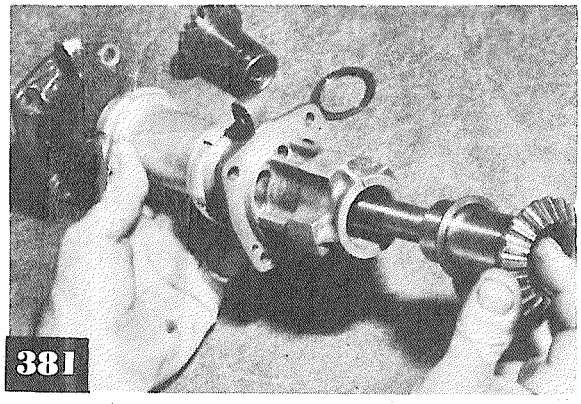
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VERTICAL DRIVE SHAFT ASSEMBLY

Slide the vertical drive shaft packings and packing nuts in their proper position on the vertical drive shaft housing. . . **377**

Place the beaded end of the housing in the lower vertical drive housing support, and place the opposite end in the upper support. Coat the threads of the upper and lower supports with a thread lubricant, and install the packing nuts using a Wrench, AT-239, making sure that the packings are properly seated in the nuts. **378**

Place the vertical drive shaft in a vise equipped with copper jaws, and drive a new cup plug in the upper end using a Drift, AT-214. . . . . **379**

Remove the shaft from the vise and place the upper thrust washer on the hub of the upper drive gear with the chamfered side toward the gear. **380**

Place the gear in position on the upper end of the shaft. Install the shaft in the housing from the upper end. **381**

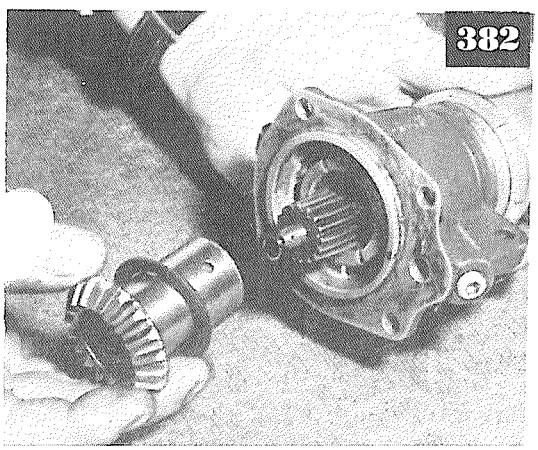
Place the lower thrust washer on the hub of the lower drive gear with the chamfered side toward the gear, and place the gear in position on the lower end of the shaft. **382**

Install a plain washer and a slotted nut on the lower end of the shaft. **383**

Tighten the nut and safety it with a cotter pin.

Place a rubber oil seal on the upper vertical drive housing support and install the assembly on the front crankcase. **384**

Secure the assembly in position with four ¼ inch self locking nuts.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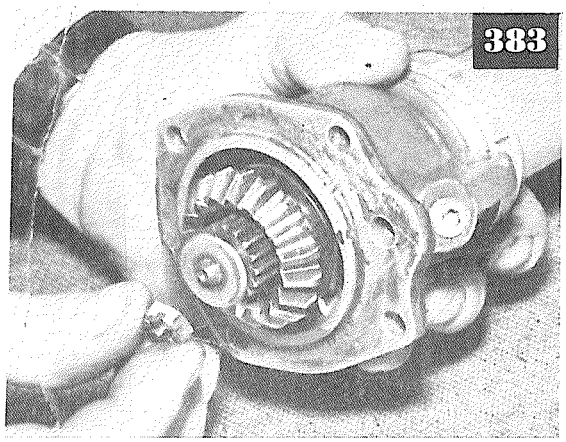
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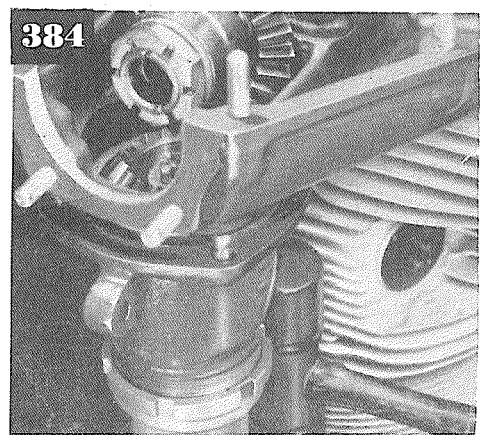
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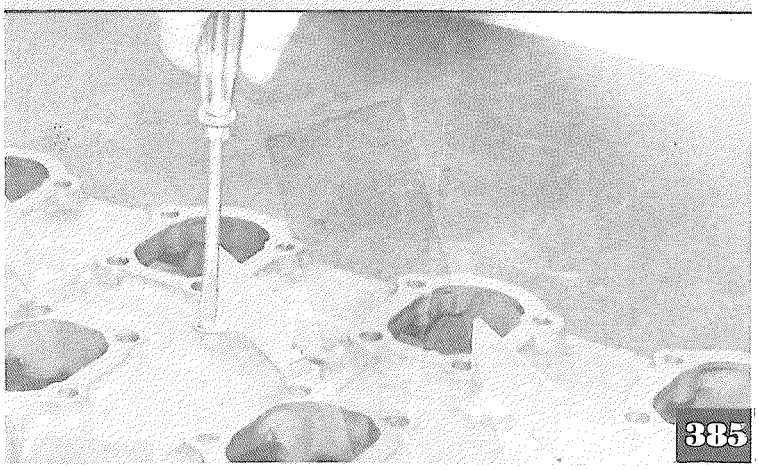
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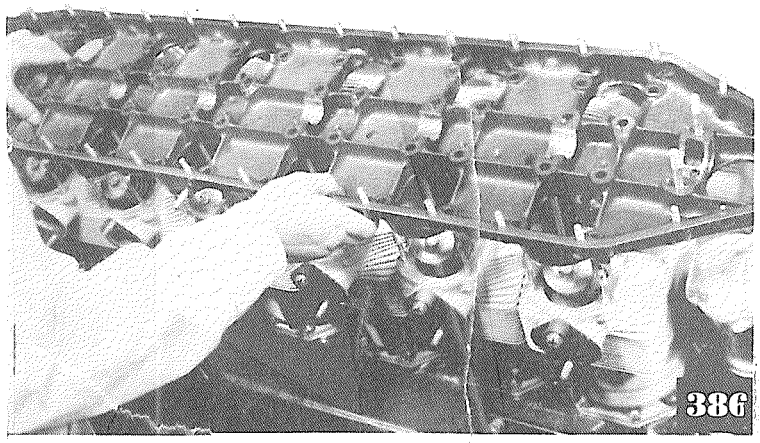
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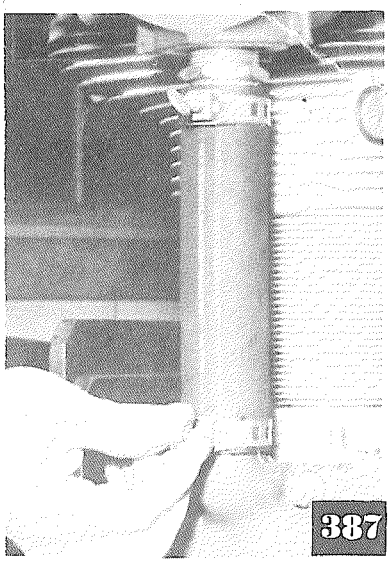
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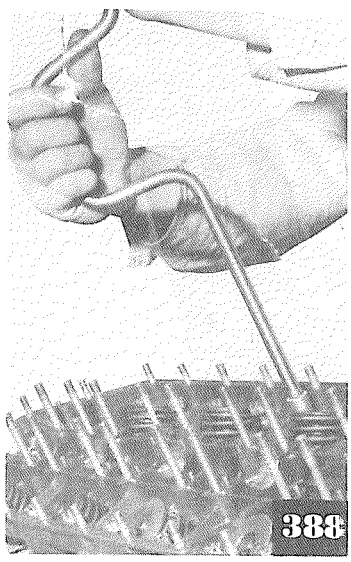
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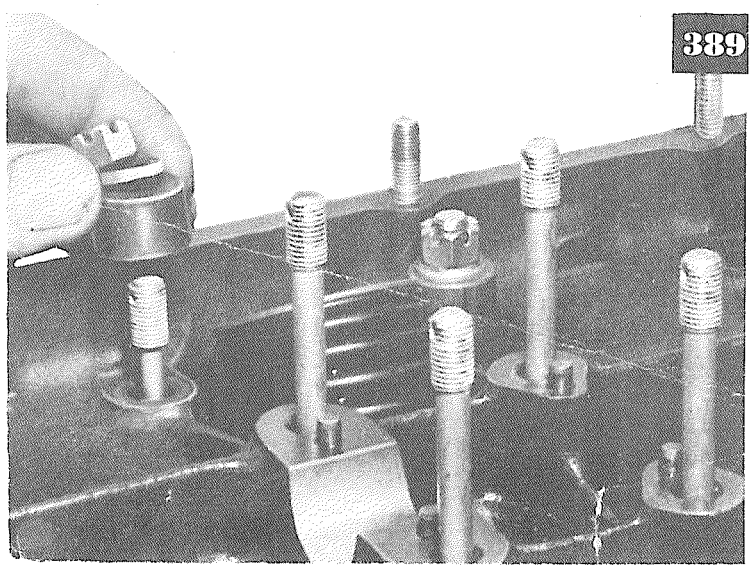
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CAMSHAFT HOUSING AND VALVE GEAR

Camshaft Housing

Fasten the four intermediate and the one center cylinder head baffles to the camshaft housing with No. 10-32 screws. **385**

Coat the cylinder head pads of the camshaft housing with sealing compound and place the housing in position on the cylinder heads, tapping it into place with a composition mallet if necessary. **386**

Slide the oil drain hose in place on the oil drain connection and tighten the two hose clamps. **387**

Place the beveled washers and nuts on the attaching studs, and tighten the nuts just enough to hold the housing securely in position. **388**

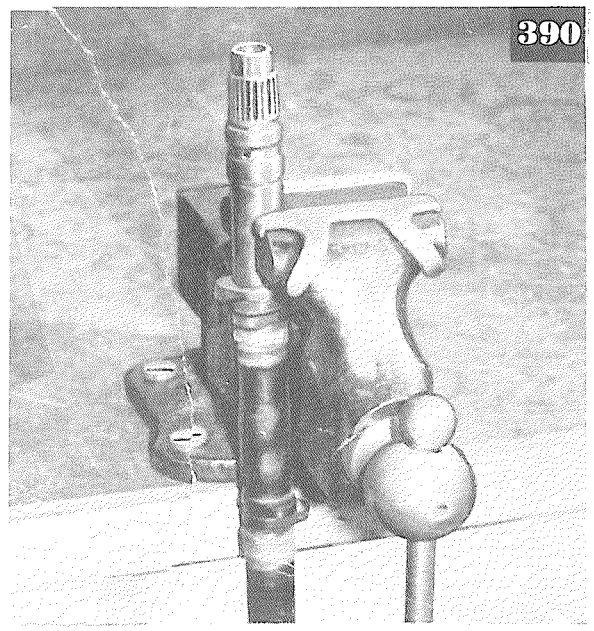
If long necked studs are installed on the exhaust and intake sides of the cylinders, a spacer must be installed before the beveled washer and nut. **389**

Camshaft Assembly

Place the camshaft, front end up, in a vise equipped with copper jaws, making sure no pressure is brought to bear on the cam lobes or journals. **390**

Using a Drift, AT-210, drive a new cup plug into the front end of the shaft.

Early engines were equipped with the old style scavenge oil drive adapter, Part Number 7308. Where this part is used, it is necessary to install a plug in the rear of the camshaft. To do this, reverse the position of the camshaft in the vise and, using a Drift, AT-211, drive in the rear cup plug.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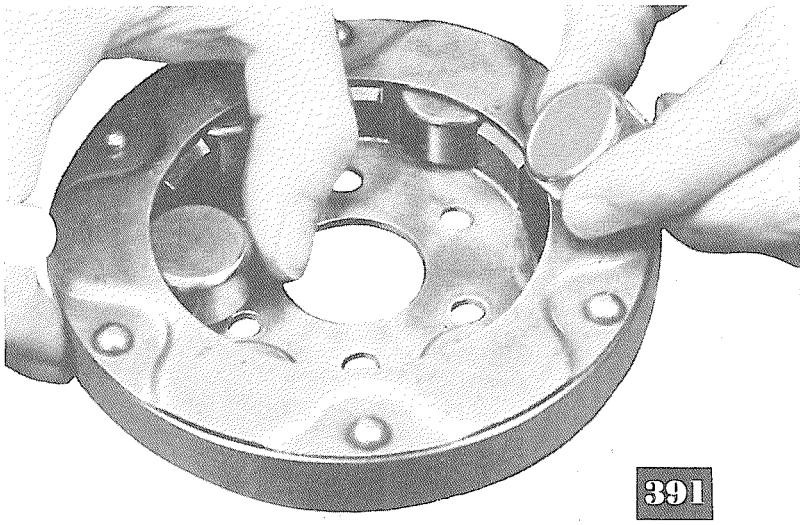


391

Engines using the new style adapter, do not need a plug in the rear of the camshaft as the oil is retained by the adapter plug.

Check the camshaft damper assembly to make sure that all the weights are in their proper position in the flywheel. 391

Place the camshaft in the vise with the flange on the rear end facing up. Mount the flywheel assembly, the scavenge oil pump adapter and the camshaft damper inner retainer on the flange so that the 5/16″ holes in each are in line. Insert the 5/16″ locating bolt and then the five ¼″ bolts and secure them with the castellated attaching nuts. 392

Tighten the nuts to the proper torque and safety them with cotter pins.

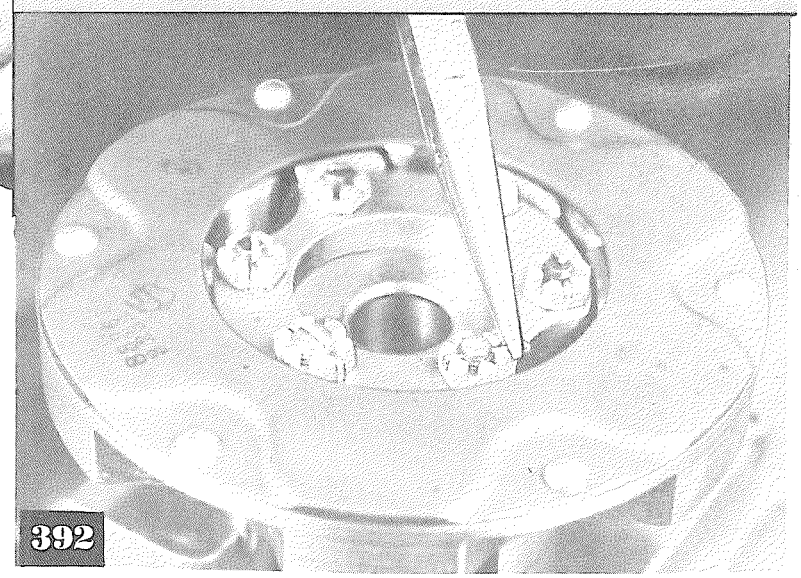
Place the thrust washer, the camshaft front gear, the plain washer and the slotted nut on the front end of the camshaft in the order named.

Slide the shouldered bushing in position on the front camshaft journal. Then place the camshaft in its proper position in the camshaft housing. 393

Making sure that the hole in the bushing fits over the hollow dowel in the housing. 394

Tighten the slotted nut, but do not safety it until after the valves have been timed.

Install the front bearing cap and the two beveled washers in their proper position and tighten the retaining nuts to a torque of about ten inch-pounds. When installing the bearing cap, make sure that the camshaft bushing is driven back against the cap so that there is no clearance between the shoulder on the bushing and the bearing cap. 395



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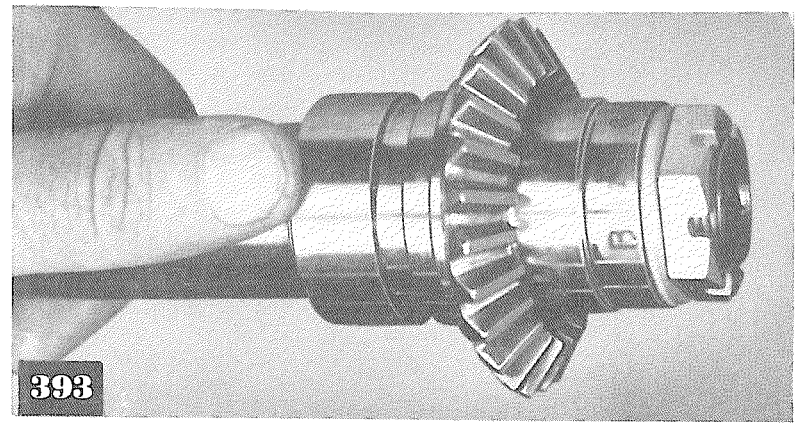

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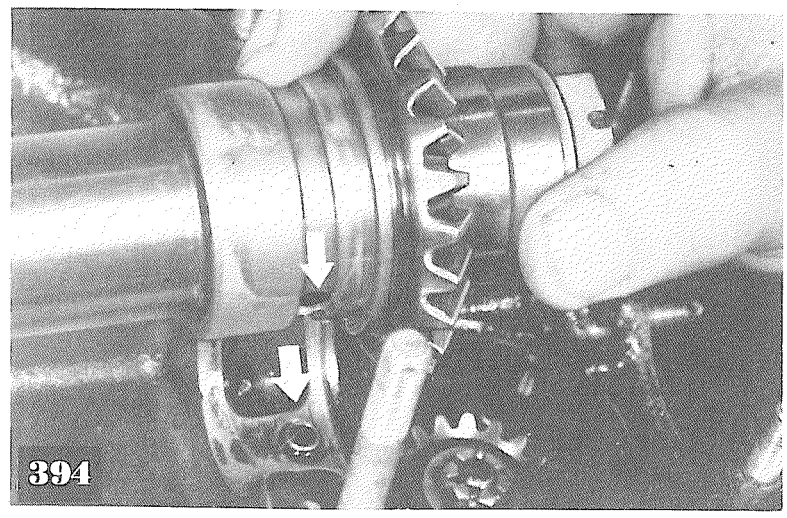

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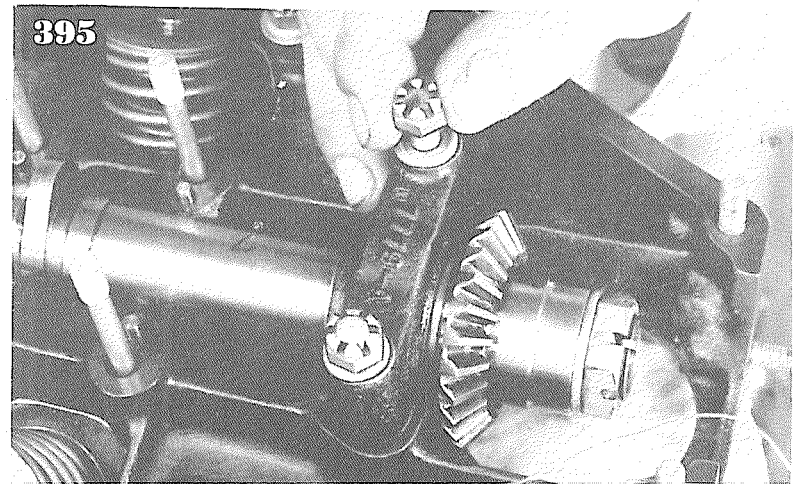

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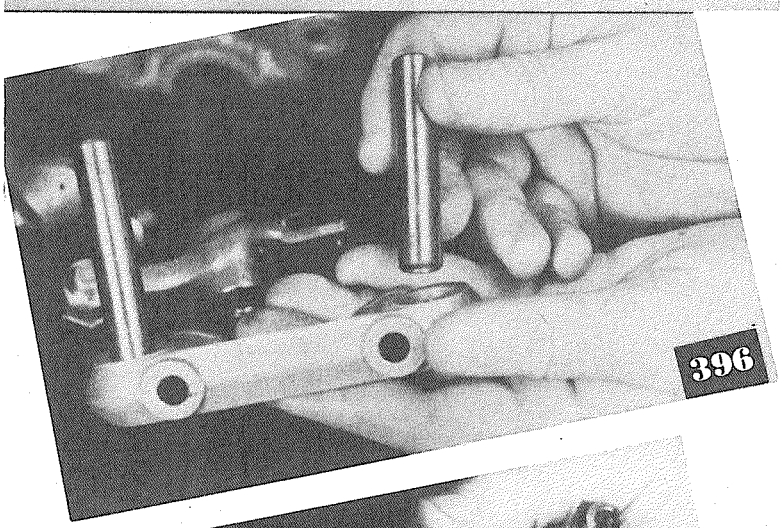
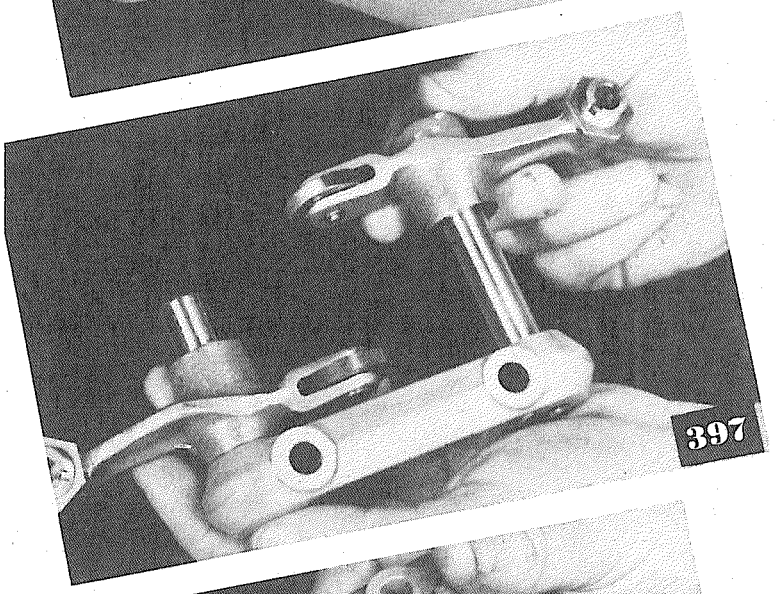
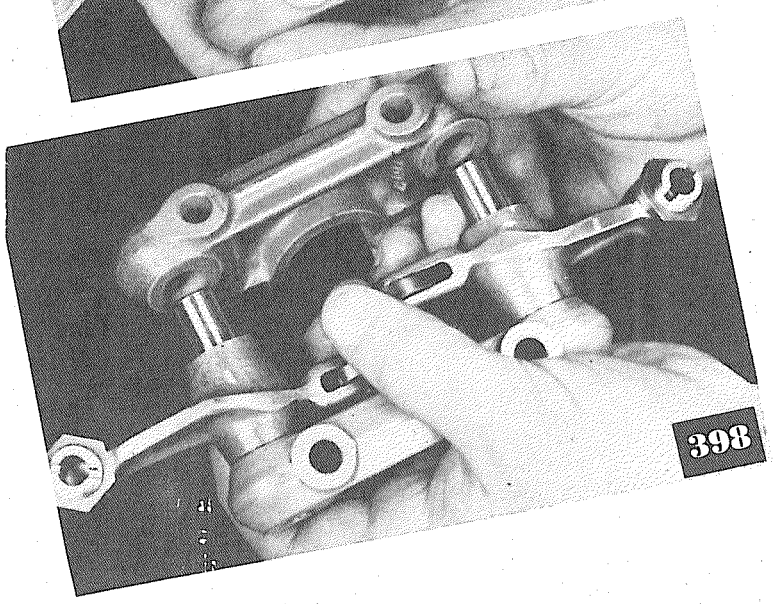






Rocker Arms and Supports

Place two valve rocker shafts into the recesses of a valve rocker support and tap them into place with a composition mallet. 396

Slide a rocker arm into position on each of the shafts. 397

Carefully place the second valve rocker support in position on the rocker shafts and tap it lightly with a composition mallet until the shafts are pushed snugly home. 398

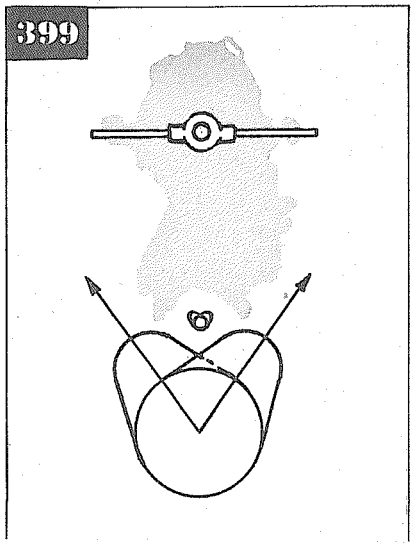
Engines 551 to 557 were originally equipped with supports having a shorter rocker arm hub and used a spacing washer on each side of the hub. Unless these parts have been replaced in a previous overhaul, they should be installed on the engine at this time.

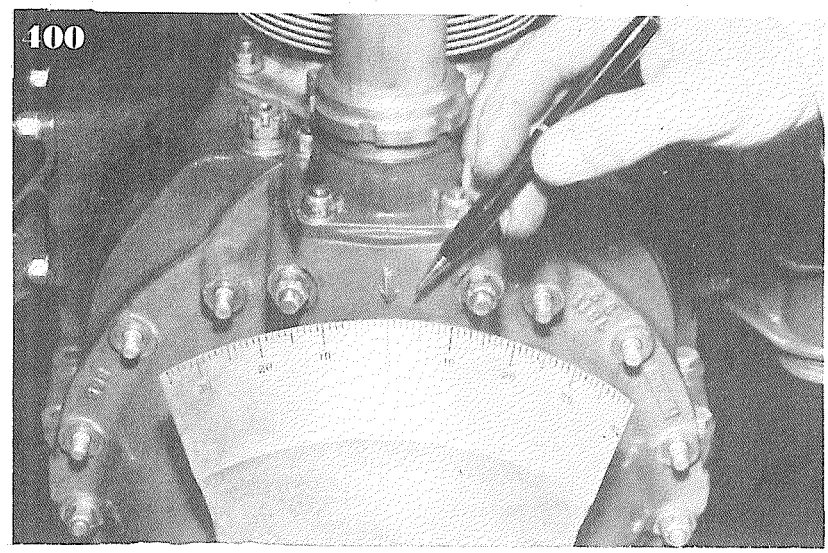
Place the Timing Disc. AT-166, in its proper position on the crankshaft and use it to rotate the shaft while the engine is being timed.

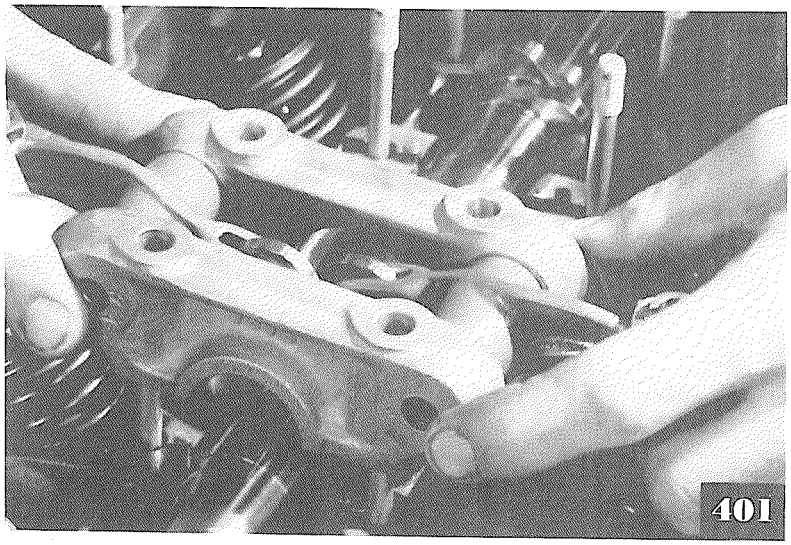
Rotate the camshaft in the housing until the cams operating the intake and exhaust valves of the number one (rear) cylinder point toward the cylinder at equal angles from the vertical center line. 399

Slowly turn the camshaft until the number one piston has reached its top dead center postion as indicated by the fact that the zero mark on the timing indicator lines up with the timing arrow on the front crankcase. 400

Lift the lower vertical drive shaft support into position against the camshaft housing. Hold in place temporarily with two nuts and washers. This will allow the lower vertical drive shaft bevel gear and the camshaft bevel gear to mesh.







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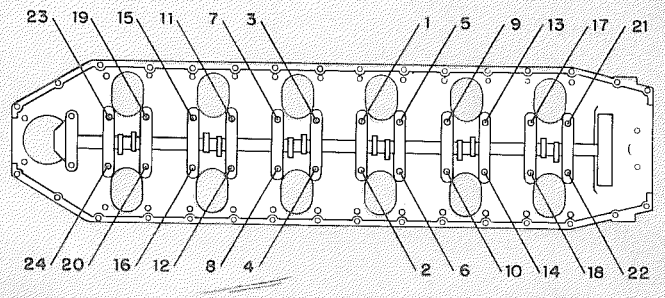


402

Place the number one valve rocker support assembly in position on the camshaft housing, making sure that the support which acts as a camshaft bearing cap is over the camshaft journal. **401**

Install the beveled washers and the retaining nuts, tightening the nuts to a torque of about ten inch-pounds.

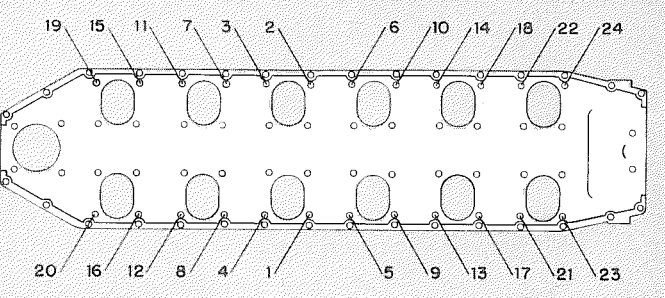
Rotate the crankshaft 120° in the direction of engine rotation and install the number five rocker support assembly. Install the numbers three, six, two and four rocker support assemblies in their proper locations in the order named making sure that the crankshaft is rotated 120° before each installation. Tighten the attaching nuts to their proper torque following the sequence indicated in **402**

After the rocker support attaching nuts have been tightened to their proper torque, the camshaft housing attaching nuts should be tightened to their proper torque following the sequence indicated in **403**

The attaching nuts may be further tightened only where it is necessary to align the nut slots and the stud holes for safetying. Under no circumstances should one of these nuts be backed off for this purpose.

Safety the front camshaft bearing cap and the camshaft housing attaching nuts with lockwire. **404**

The rocker support assemblies are safetied with special lockpins. **405**



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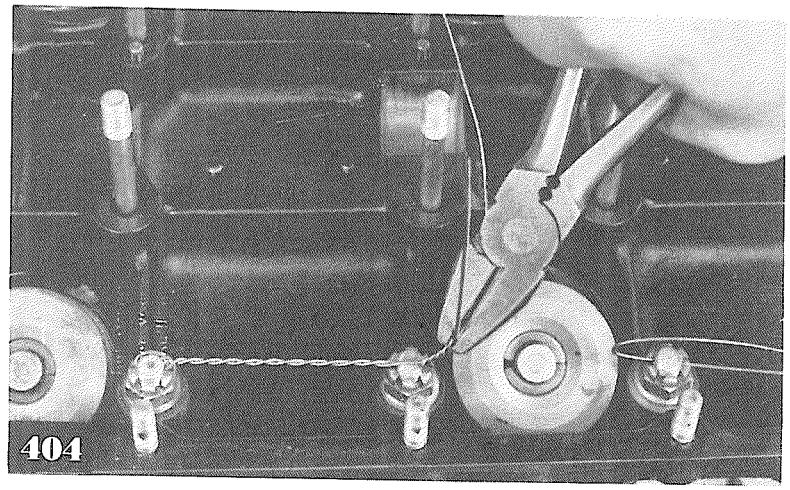

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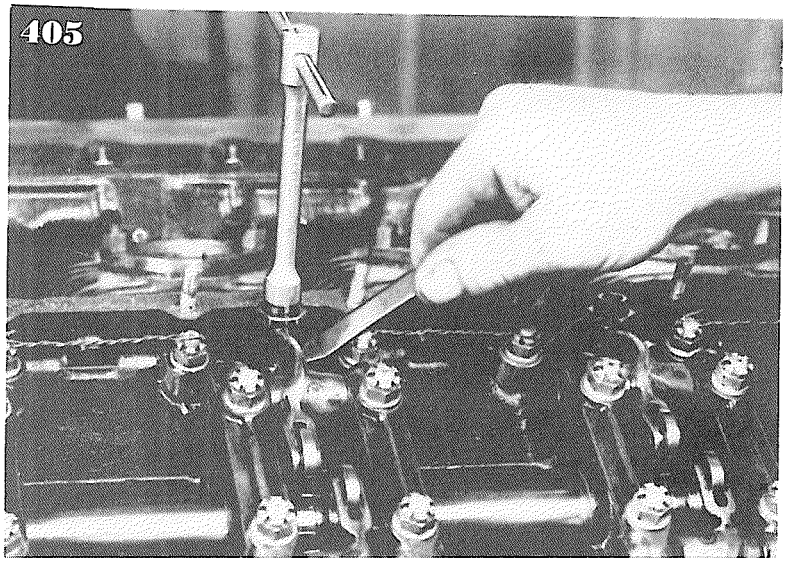


405

Valve Timing

The temporary timing described in the previous chapter is necessary to prevent damage caused by pistons striking open valves while the crankshaft is being rotated.

	Opens	Closes	Clearance	
			For Timing	For Running
Intake Valve	15° Before Top Center	65° After Bottom Center	.015″	.015″
Exhaust Valve	70° Before Bottom Center	30° After Top Center	.015″	.030″

Table for Timing the Engine

The following is the correct procedure for timing the engine.

Using a Wrench, AT-160, to turn the valve adjusting screw, adjust the clearance of all intake valves to .015″ and the clearance of all exhaust valves to .030″, using a Feeler Gage, AT-11. 406

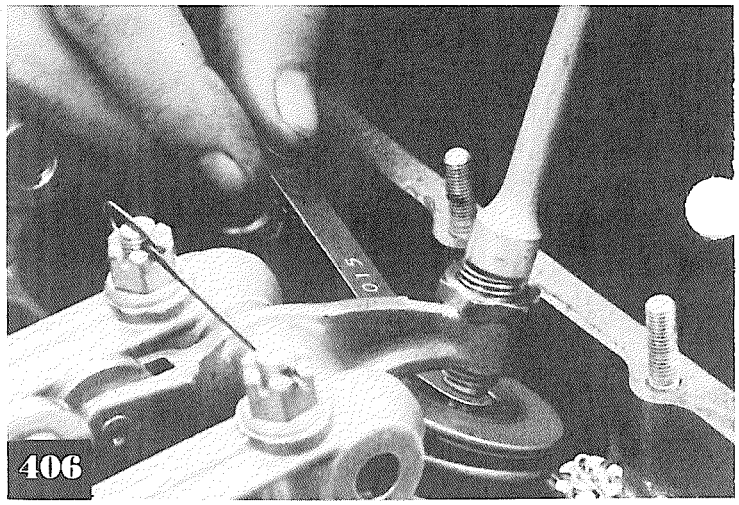
Turn the crankshaft in the direction of engine rotation until the intake valve in the number one cylinder is just about to open. This will be the point where the valve rocker roller can no longer be turned by the fingers due to the pressure exerted by the cam.

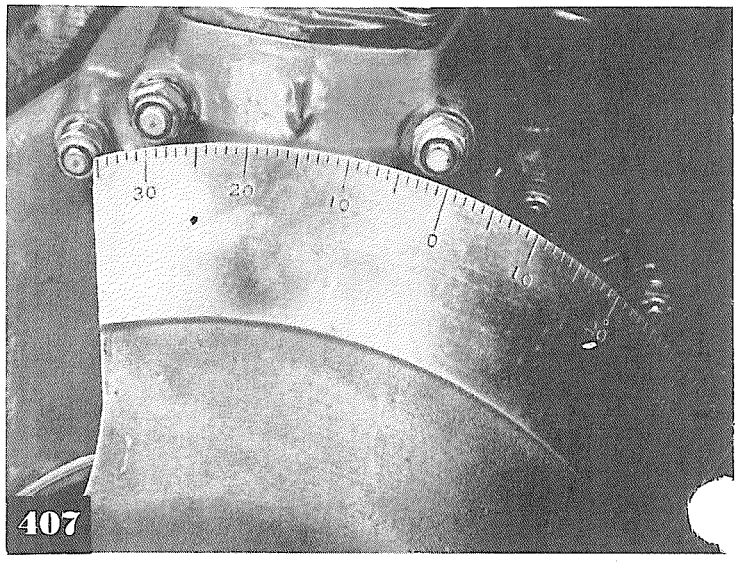
Remove the two nuts temporarily holding the lower vertical drive support in contact with the camshaft housing. Allow the support to slide down on the vertical drive shaft housing, causing the lower vertical drive bevel gear to drop out of mesh with the camshaft bevel gear.

Turn the crankshaft in the direction of the engine rotation until the number one piston is exactly 15° before top dead center. If the crankshaft is already past this point, turn it backwards about 10° past this point and then forward again, to eliminate the effect of backlash. 407

Raise the lower vertical drive support to its proper position, making sure that the camshaft does not turn as the gears mesh. If the gears do not mesh properly, remove the camshaft gear, rotate it slightly and reinstall; then try meshing the gears again. Secure the housing in position temporarily with two attaching nuts and washers. Turn the crankshaft backward about 30° and then slowly move it forward by tapping the handle of the timing disc until the number one intake valve rocker roller can no longer be turned by hand.

Check the valve opening point as shown on the timing indicator. If it is incorrect,





remove the two nuts and washers attaching the lower vertical drive support to the camshaft housing, and allow the support to slide down on the vertical drive housing. This will cause the lower vertical drive gear to fall free of the front camshaft bevel gear. To advance the valve opening, remove the front camshaft gear from the shaft and turn it against the direction of normal camshaft rotation and then replace it on the shaft.

To retard the valve opening, turn the gear in the same direction as camshaft rotation. 408

When replacing the gear on the camshaft, make sure that the thrust washer is in its proper place on the shoulder of the camshaft. 409

Turning the gear the distance of one spline will change the valve timing 1-1/3°.

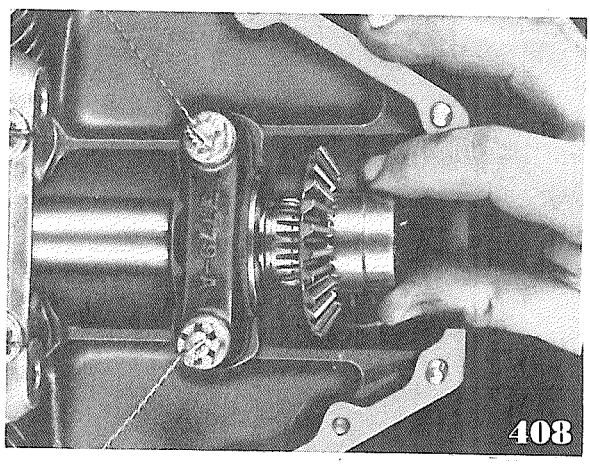
Restore the lower vertical drive support to its correct position on the camshaft housing, again temporarily securing it with the two attaching nuts and washers. Check the

timing by following the procedure previously outlined.

To check the point at which the exhaust valve of the number one cylinder closes, insert a .015″ Feeler Gage, AT-11, between the valve stem and the adjusting screw. Then turn the crankshaft backwards until the valve opens. Turn the crankshaft slowly forward while holding a steady tension on the feeler gage. When the feeler gage can suddenly be drawn clear, the exhaust valve is just closing.

Check for balance in timing between the intake and exhaust valve of the number one cylinder. A variation of plus or minus 2° is permissible.

After the engine has been properly timed, remove the two nuts and washers, holding the lower vertical drive support to the camshaft housing, and allow the support to slide down on the vertical drive shaft housing. Apply sealing compound to the parting surface of the support and use silk thread as a seal. The silk thread should be placed on the parting surface in such a manner that it is located on the inside of the stud holes and on the outside of the oil passage.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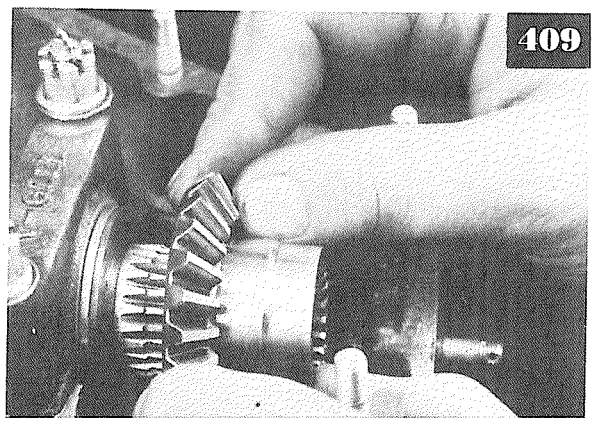
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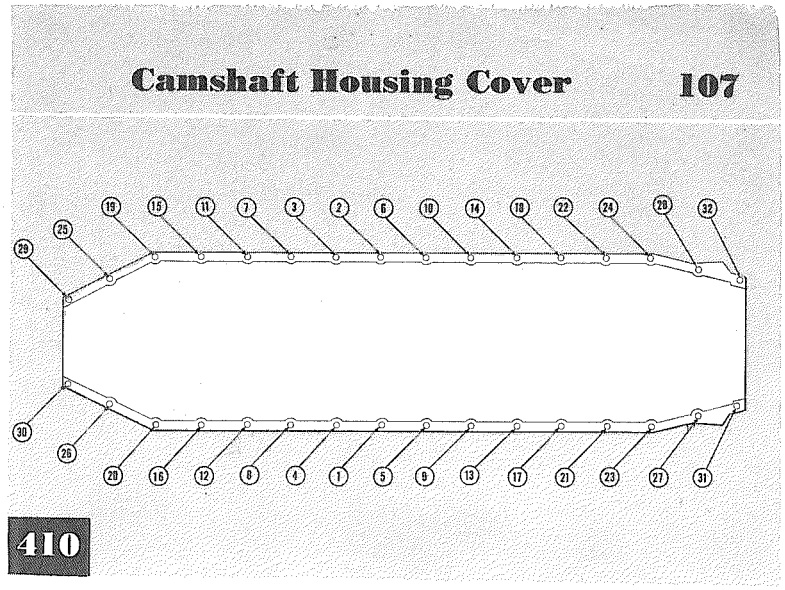

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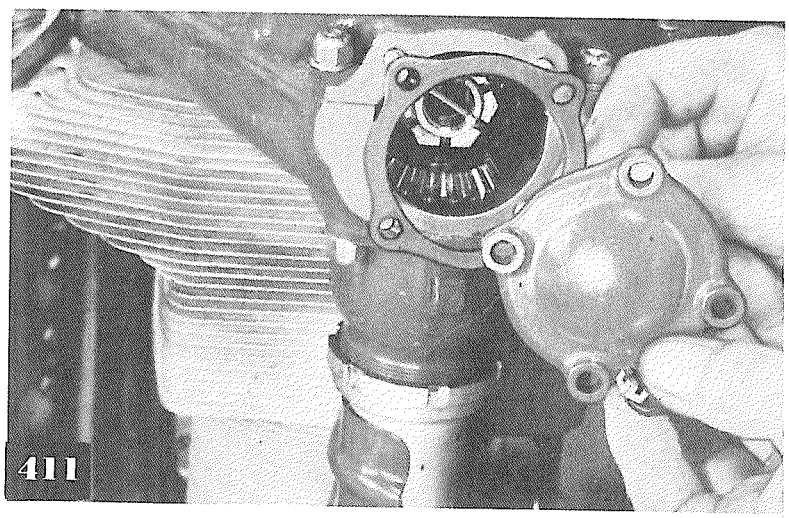

411

Raise the support to its proper position on the camshaft housing and secure it in place by installing the four attaching nuts and tightening them to their proper torque.

Recheck the engine timing to make sure it has not been changed by the disengaging and reengaging of the bevel gears.

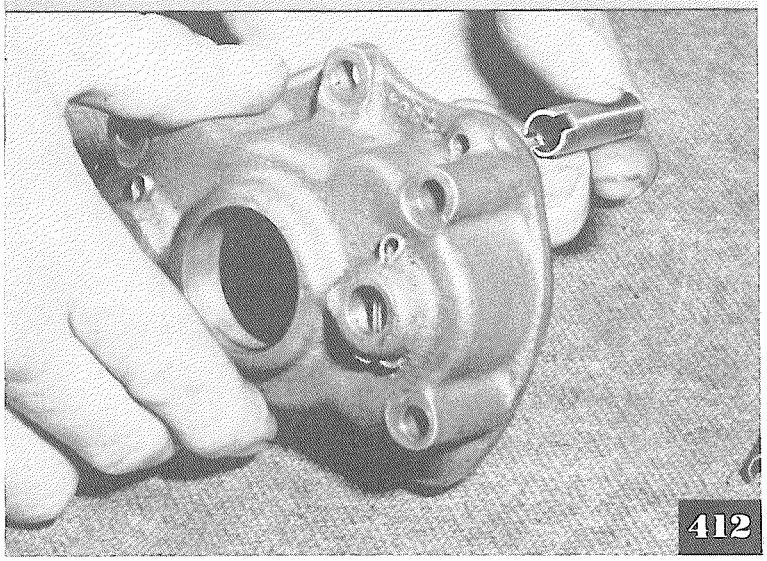
Camshaft Housing Cover

Apply a coating of sealing compound to the parting surface of camshaft housing cover and place the cover in position on the housing. Install the attaching nuts finger tight. When all the nuts are installed, they should be tightened to their proper torque, starting with the nuts in the center and working toward the front and rear. . . . **410**

The rear nut on both sides of the cover should not be tightened at this time.

Place a gasket on the camshaft housing assembly front parting surface, and install the front cover. **411**

Install and tighten the slotted attaching nuts, safetying them with lockwire.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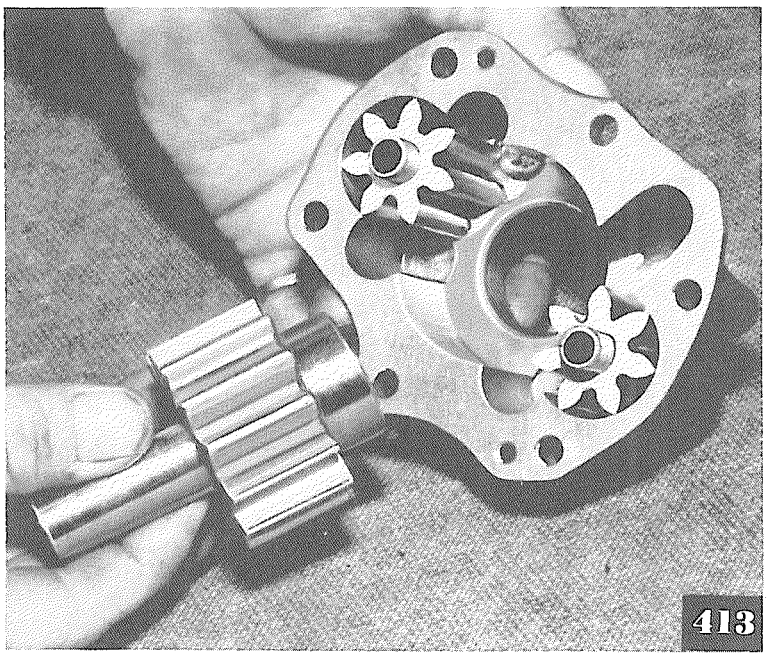
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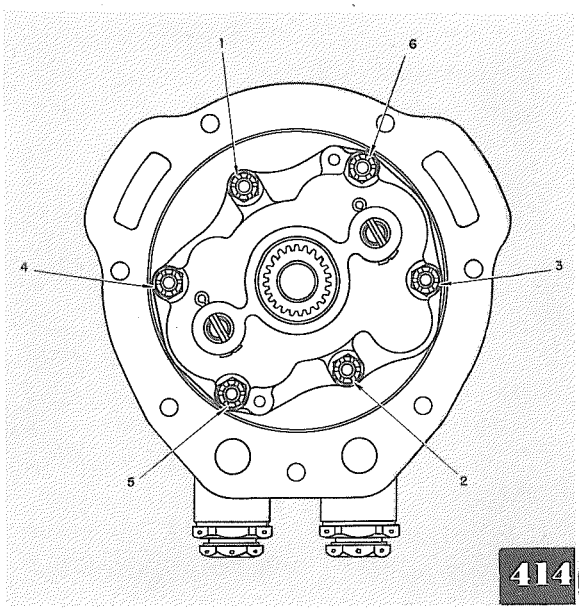

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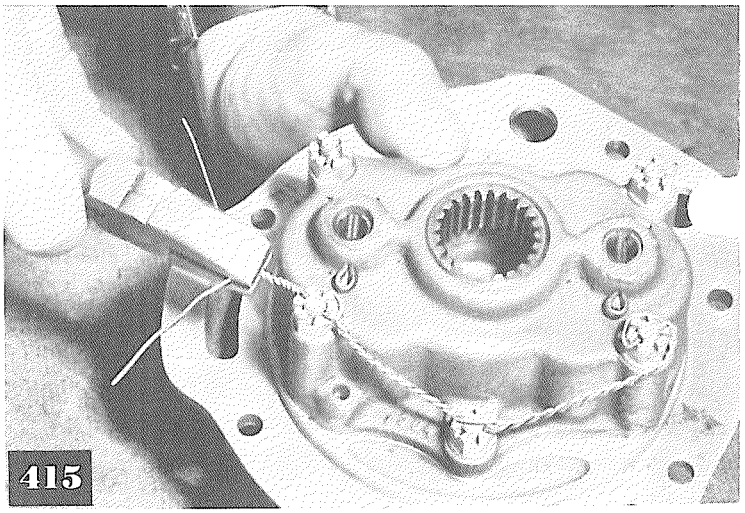
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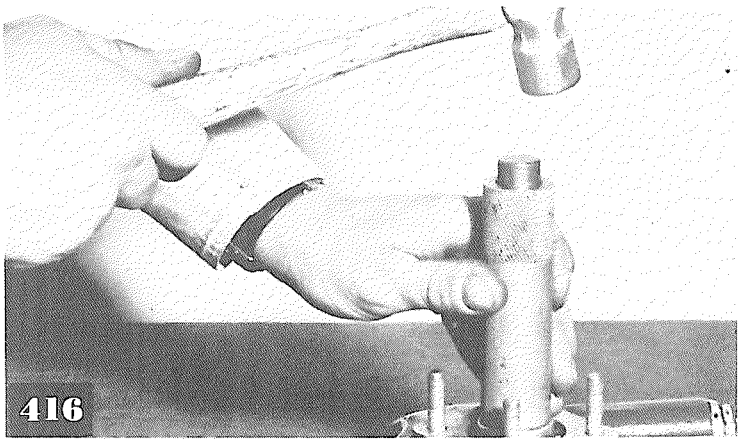
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Scavenge Oil Pump

Install the scavenge oil pump idler gear shafts in the scavenge oil pump cover and secure them in position with cotter pins. 412

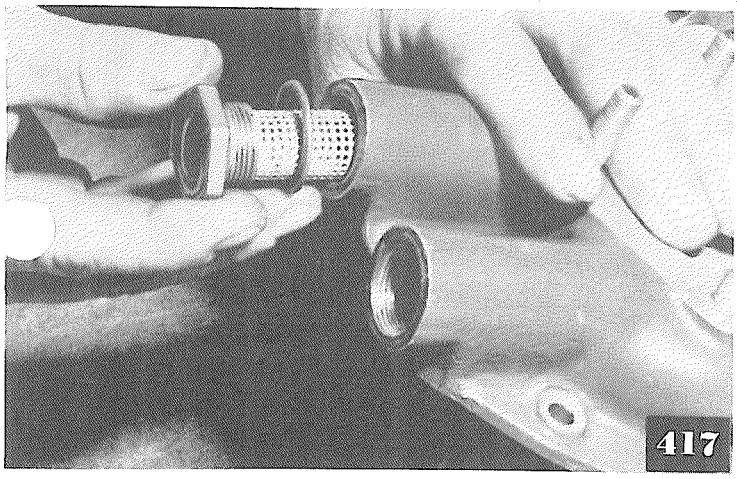
Place all the gears in their proper locations, ...413

and mount the cover assembly on the scavenge oil pump housing. Install the attaching nuts and washers, tightening the nuts to their proper torque in the order shown in 414

After the nuts have been tightened to the proper torque, they may be further tightened where necessary to align the nut slots with the holes in the studs for safetying. Rotate the gears by hand as a check for freedom of movement. Safety the attaching nuts with lockwire, being careful not to place the lockwire over the ends of the studs. ..415

Using a Drift, AT-187, install a new oil retainer in the scavenge oil pump housing. 416

Place a new copper asbestos gasket on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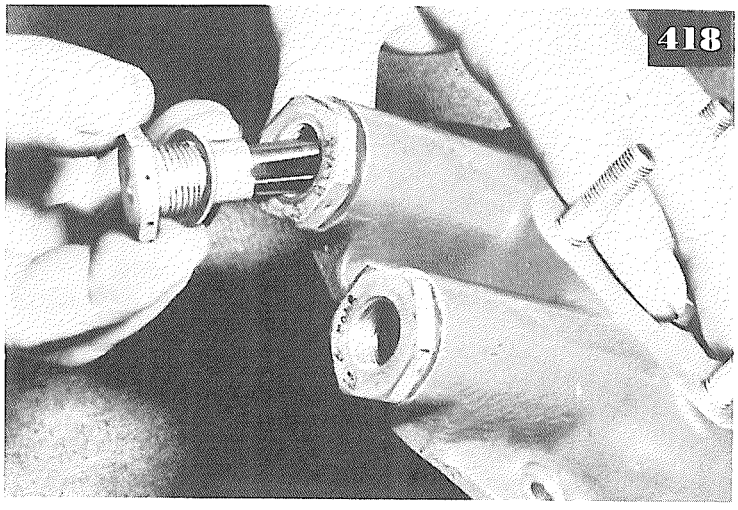
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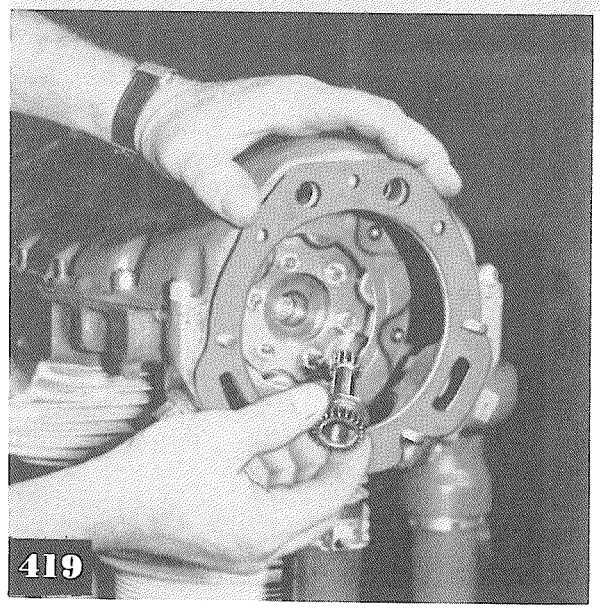
each of the two finger strainers and install the strainers in the housing. 417
Put a copper asbestos gasket on each of the two magnets and insert the magnets in the finger strainers. 418

Place the scavenge oil pump drive shaft in position in the camshaft flywheel. .419
Place a gasket on the parting surface of the scavenge pump housing and install the housing in position on the camshaft housing assembly. 420
To successfully complete this operation, it may be necessary to rotate the crankshaft to permit the splines of the scavenge oil pump drive shaft and gear to mesh. Secure the housing in position, using four self locking nuts and three cap-screws.

After the capscrews are securely tightened, they should be safetied with lockwire. Tighten the rear nut on each side of the camshaft housing to its proper torque. Place a gasket, a fibre spacer, another gasket, and a replacement cover on the fuel pump mounting pad located on the scavenge oil pump, and secure with four nuts. 421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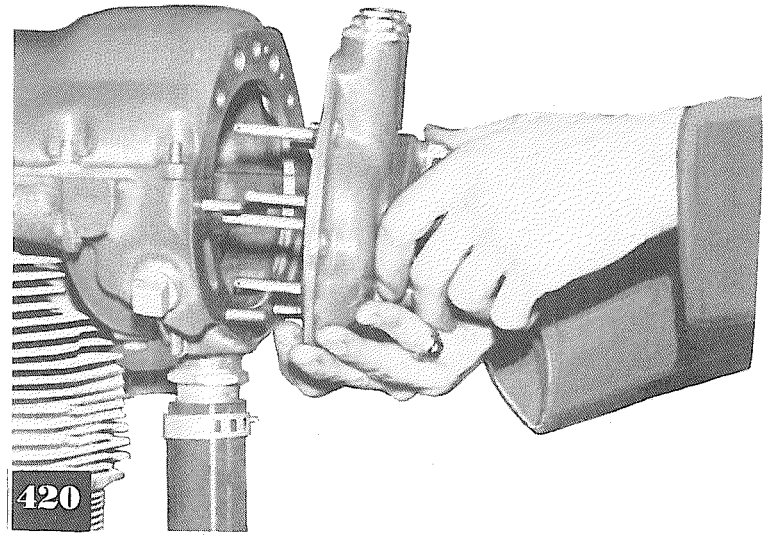
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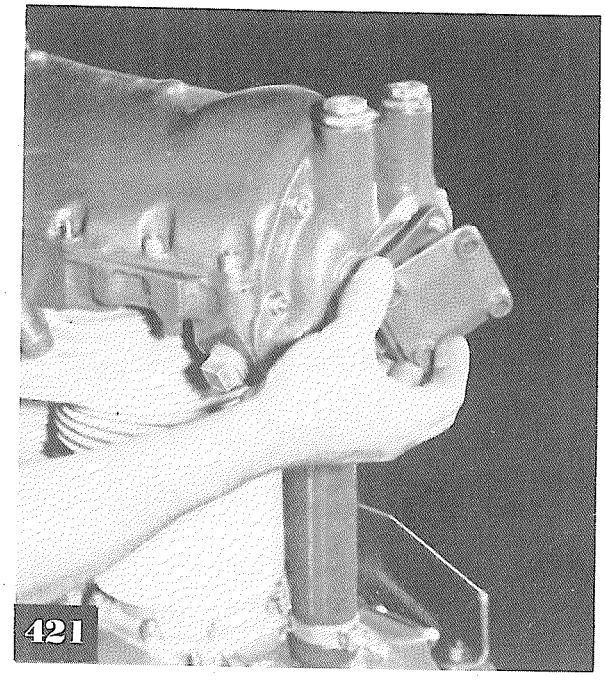
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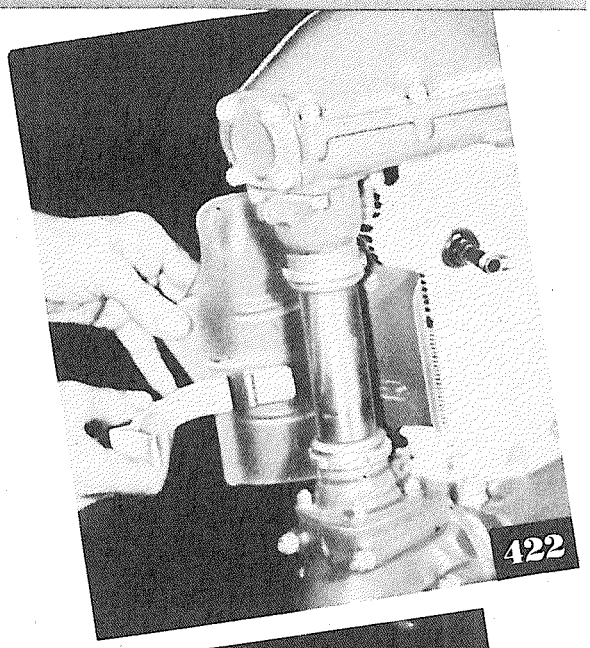
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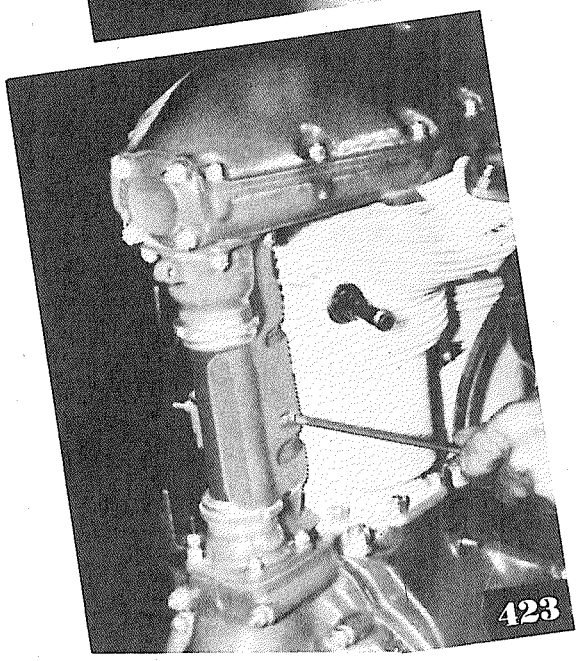
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BAFFLES

Place the front cylinder baffle in position between the vertical drive shaft housing and the number six cylinder. Locate the front baffle spring so that it is held in place by the baffle hinge and the vertical drive housing. 422

Insert the long fillister head screw through the baffle, engage with the anchor nut on the spring and tighten. 423

When the screw is securely tightened, the clamping action will hold the baffle assembly in its proper place.

To install the intermediate baffle assemblies, the following procedure should be followed.

Assemble the baffle screw and clamp. Place the baffle in position between two cylinders on the intake side of the engine, ...424

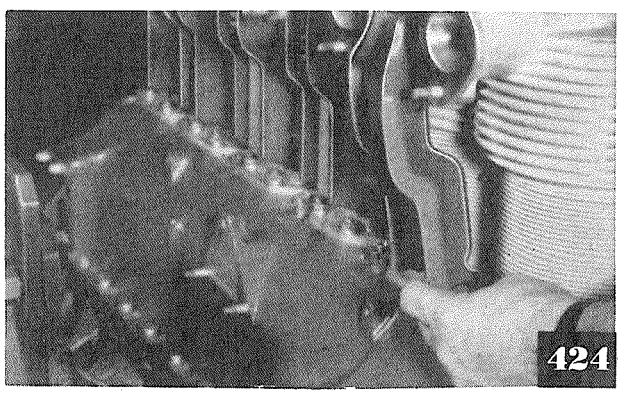
and the clamp and screw on the exhaust side. 425

Secure the baffle into place by tightening the screw into the baffle nut.

INTAKE MANIFOLD SYSTEM

Slip the intake pipe packing nuts, the packing nut washer, and the pipe packing over the plain ends of the intake pipes. 426

Place the intake pipes in position on the intake manifold, ...427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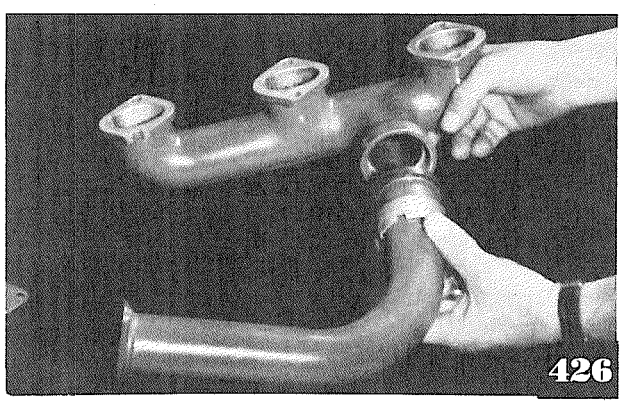
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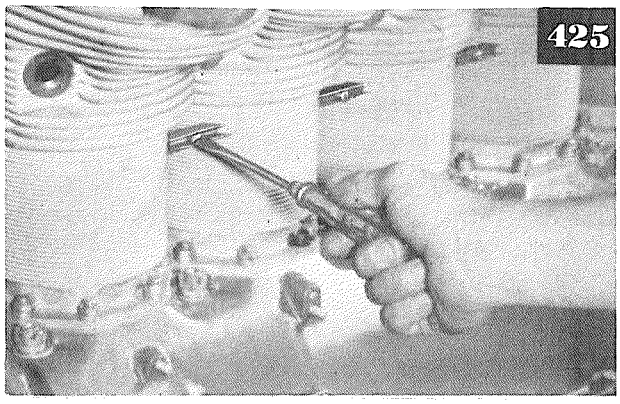
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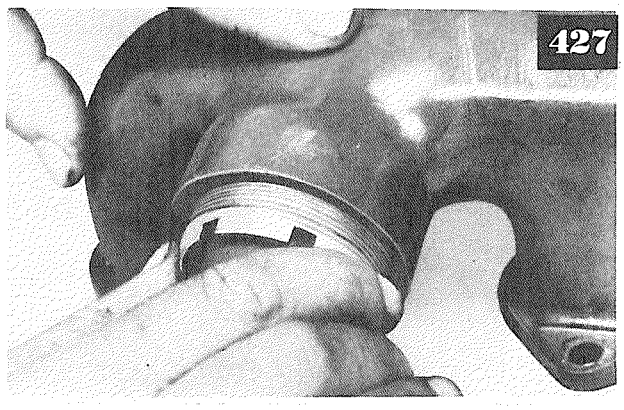
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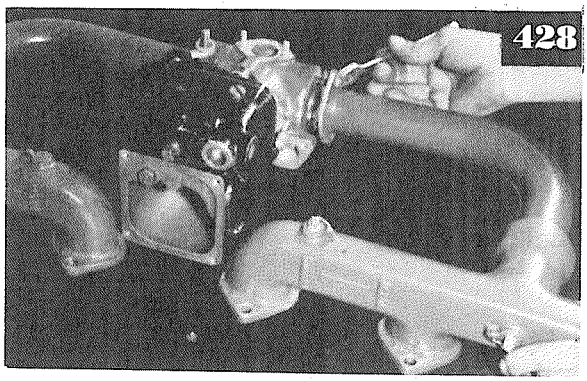
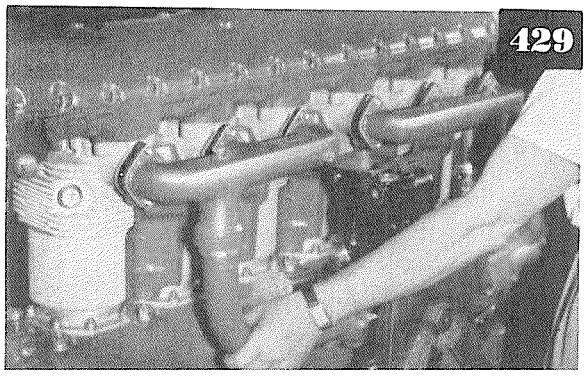
and tighten the packing nut finger tight. Place a gasket on the hotspot attaching flange of each intake pipe and place the pipes in position on the hotspot. .....**428** Attach the pipes to the hotspot with capscrews, and after the screws are securely tightened, safety them with lockwire. Place a new manifold gasket on each of the intake ports and place the entire induction assembly in position on the ports. .....**429** Install the attaching locknuts and tighten them to their proper torque in the order shown in figure .....**430** Secure the hotspot in position by installing the attaching locknuts. Note that one of the three attaching nuts is located behind the hotspot, facing the cylinders.

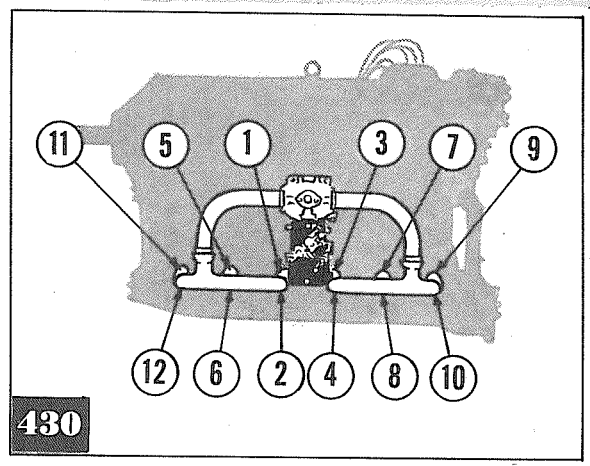
Using a Wrench, AT-46, tighten the intake pipe packing nuts, ...**431** making sure that the packings are properly seated.

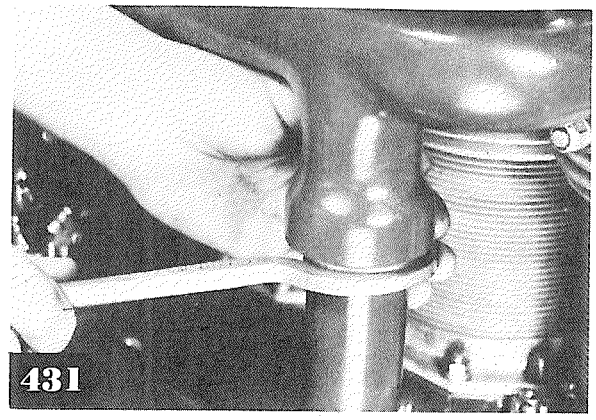
Try to insert a .0015″ feeler gage between the manifold flange and the cylinder intake ports, ...**432** and between the intake pipe flanges and the hotspot port as a test to make sure that the joints are tight.

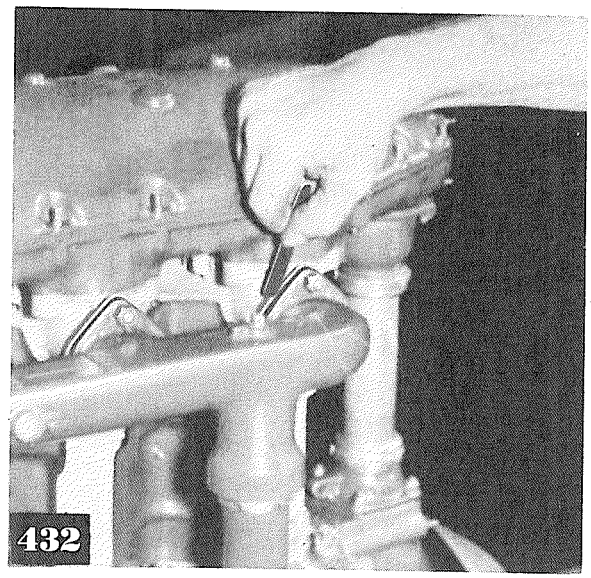
Mount the carburetor on the hotspot and secure it in position by tightening the castle nuts to their proper torque. .....**433** After the nuts have been tightened, they should be safetied with wire.

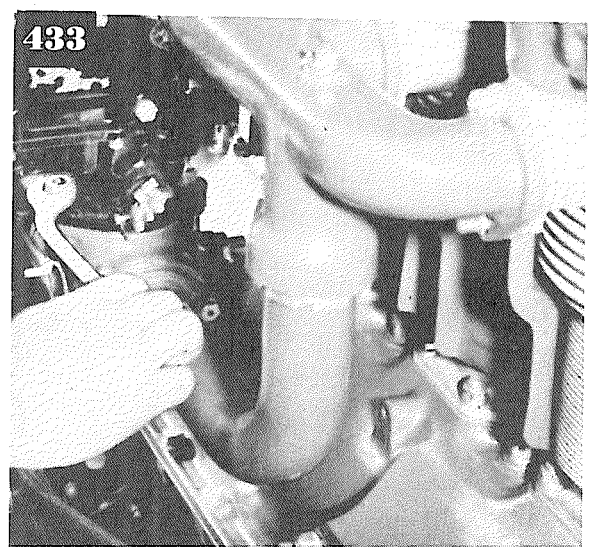


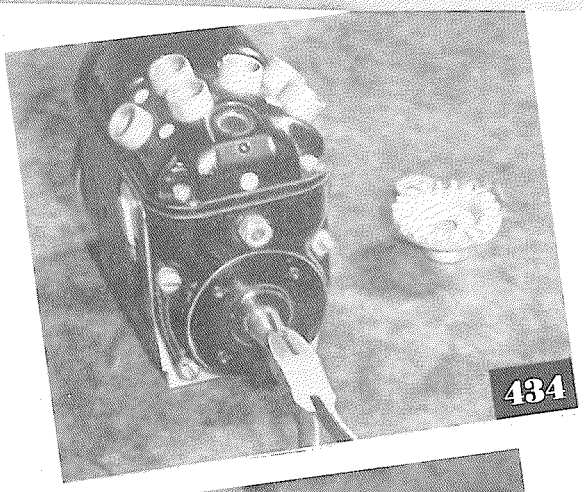








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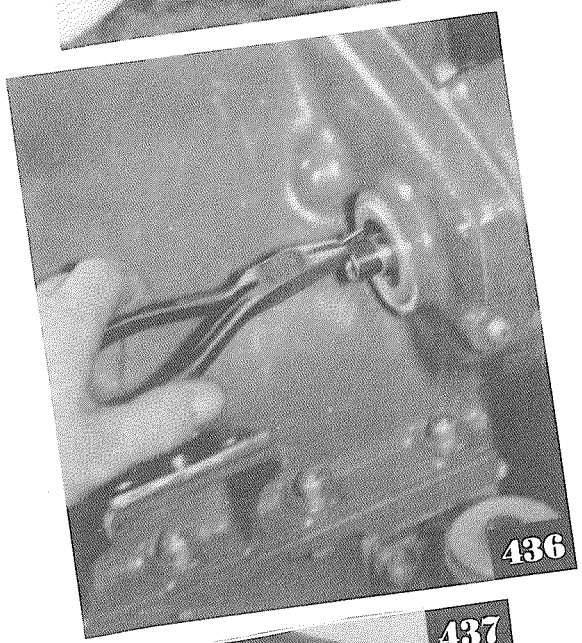
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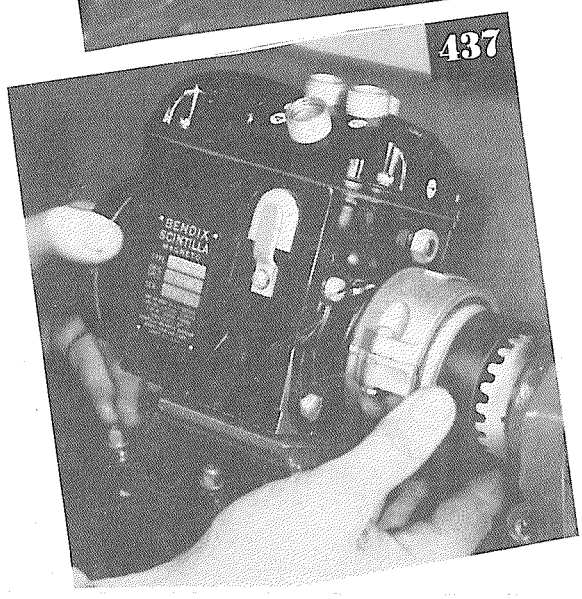

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IGNITION SYSTEM

Ignition Manifolds

Remove the pins holding the cradle of the engine assembly stand and rotate the engine back to the normal position. Replace the retaining pins immediately.

Install the ignition manifolds into position on each side of the engine and secure each manifold to the crankcase with four capscrews, plain washers and lock washers.

Magnetos

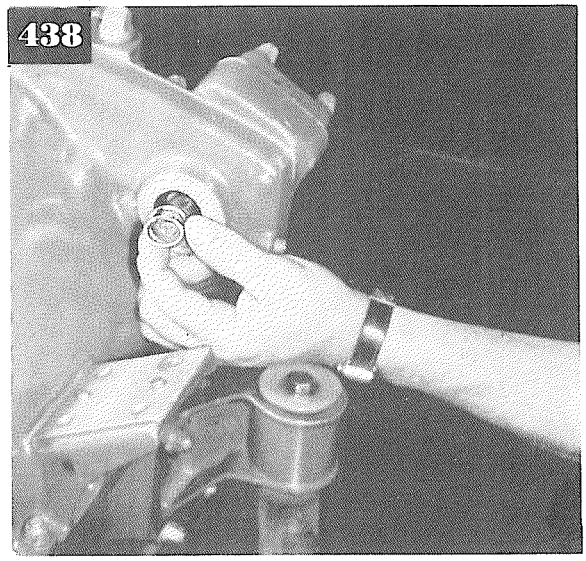
Fit a woodruff key in the shaft of each of the magneto drive gears. **434**
Put the magneto drive couplings in place on the shafts, tapping them with a fiber mallet if necessary. **435**

Install the attaching nuts and washers. After the nuts have been tightened, they should be safetied with cotter pins.

Place a woodruff key in the keyway on the shaft of the right magneto, ...**436**
stoning the key if necessary to insure a proper fit.

Place the magneto coupling on the magneto shaft, secure it in place by tightening the attaching nut and washer. After the nut is thoroughly tightened, it should be safetied with a cotter pin. Install a rubber intermediate coupling on each magneto drive coupling and then install magneto and coupling together, ...**437**
making sure the magneto is properly seated on the locating dowels.

Check for indications of excessive end clearance between the couplings. If such an indication is present, it may be eliminated by the addition of shims behind the magneto drive couplings. **438**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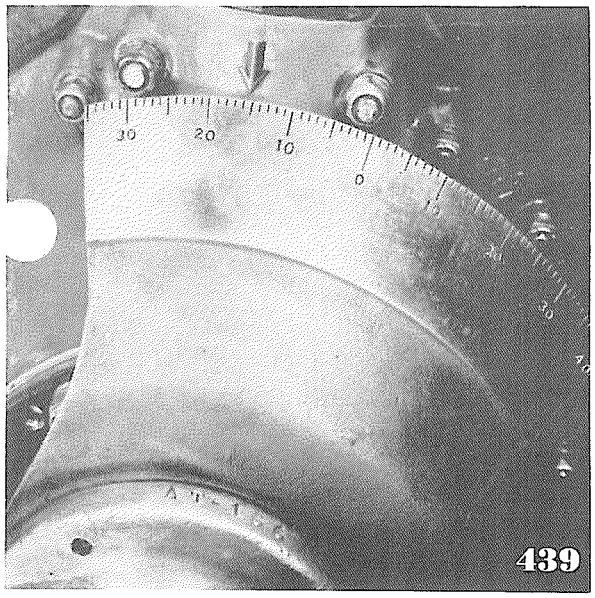

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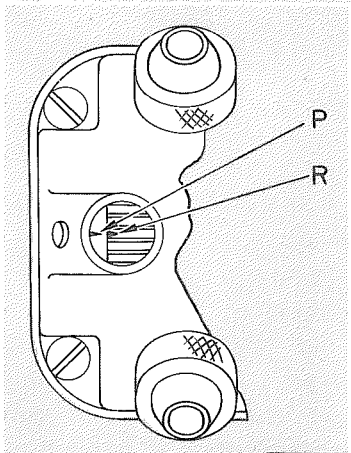

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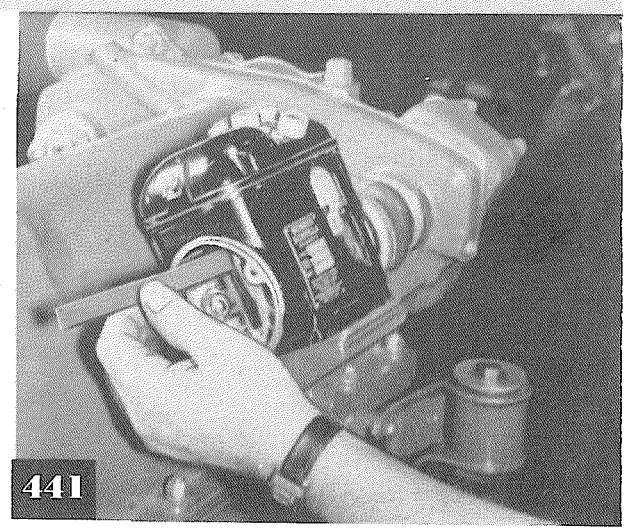
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Place the Timing Indicator, AT-166, on the crankshaft and the Top Dead Center Indicator, AT-112, in the spark plug insert in the cylinder head.

Turn the crankshaft in the direction of engine rotation until the number one piston is at the point specified in the following table on the compression stroke. **439**

Model	Left Magneto	Right Magneto
6-440C-2	22° Before Top Center	22° Before Top Center
6-440C-3-4-5	25° Before Top Center	25° Before Top Center

Remove the right magneto from the mounting pad and rotate the magneto shaft until the white mark on the distributor gear appears opposite the timing pointer in the window. **440**

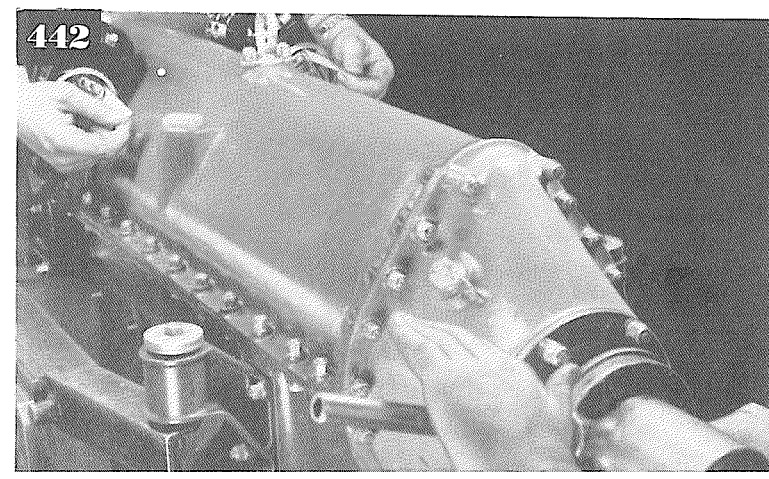
Place the rubber intermediate coupling on the magneto driven coupling and, holding the couplings to prevent the shaft from turning, replace the magneto on the mounting pad. If it is found that the rubber intermediate coupling does not readily engage with the drive coupling on the engine, it should be removed and rotated until all three couplings engage without interference. Temporarily secure the magneto in position on the mounting pad with two capscrews.

Remove the left magneto from the mounting pad and turn the shaft against the normal direction of rotation until the white mark on the distributor gear appears opposite the timing pointer in the window. It is necessary to rotate the magneto shaft against the normal direction of rotation to prevent the engagement of the impulse coupling. Place the rubber intermediate coupling on the magneto coupling, and proceed with the installation of the left magneto as with the right magneto.

Turn the crankshaft against the direction of engine rotation for about ten degrees. Do not turn the shaft more than ten degrees, otherwise the impulse coupling will engage and make it impossible to check the timing of the right magneto. If this occurs, turn the crankshaft in the normal direction of rotation until the impulse coupling releases. After this, turn the crankshaft against the direction of normal rotation to a position ten degrees before the firing point.

Place a .0015 inch feeler gage or a piece of cellophane between the breaker points of each magneto. **441**

Very slowly rotate the crankshaft in the direction of engine rotation by tapping the handle of the timing disc while exerting a light finger pull on the feeler gages. . .**442**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As soon as the breaker points open and release the gages, stop turning the crankshaft and check the timing as indicated on the timing indicator.

If the breaker points of either magneto do not open at the point specified in the above table, the rubber intermediate coupling should be removed and rotated with respect to both the driving and driven magneto couplings. To advance the opening point, turn the coupling in the direction of engine rotation; to retard the opening point, turn the coupling against the direction of engine rotation. 443

Rotating the coupling one tooth will change the timing 2/3 degrees.

When the timing of both magnetos is correct, install and tighten all four attaching cap screws and safety them with lockwire.

Connect the magneto terminals on the ignition wires to the magnetos, making sure that numbers on the ignition wires correspond to the numbers on the magneto binding posts. 444

The timing indicator should now be removed from the crankshaft.

Spark Plugs

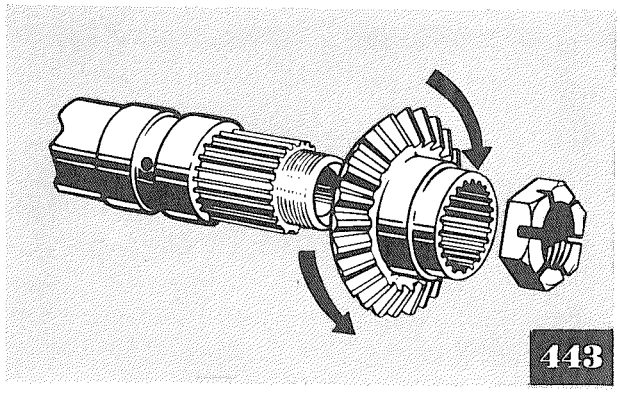
Remove the dummy plugs from the spark plug inserts in the cylinder head. Place a new copper gasket on the base of each spark plug and insert the spark plug into the cylinder head. 445

To facilitate the installation or removal of spark plugs, the following wrenches are available.

For unshielded spark plugs, use Wrench, AT-39; for shielded spark plugs, use Wrench, AT-153.

THRUST BEARING NUT

Place a Wrench, AT-137, on the thrust bearing nut, and tighten the nut by tapping the wrench with a lead mallet. 446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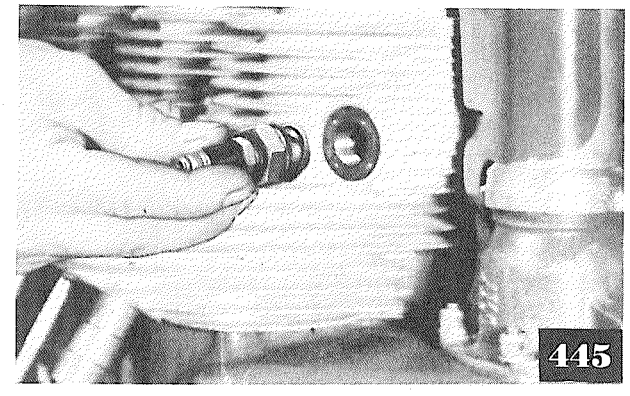
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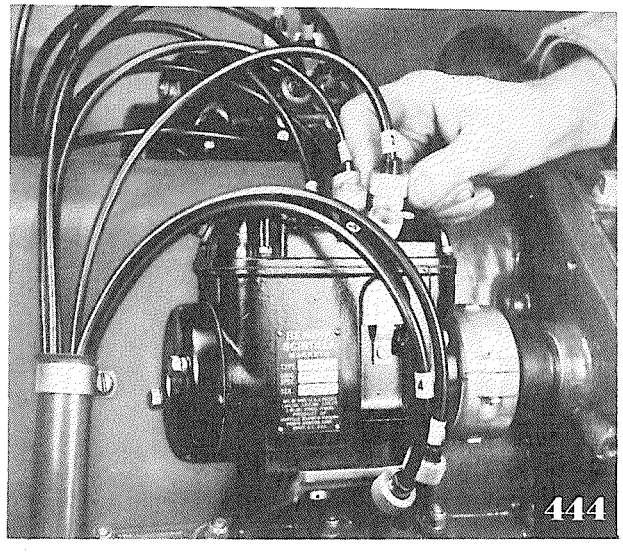
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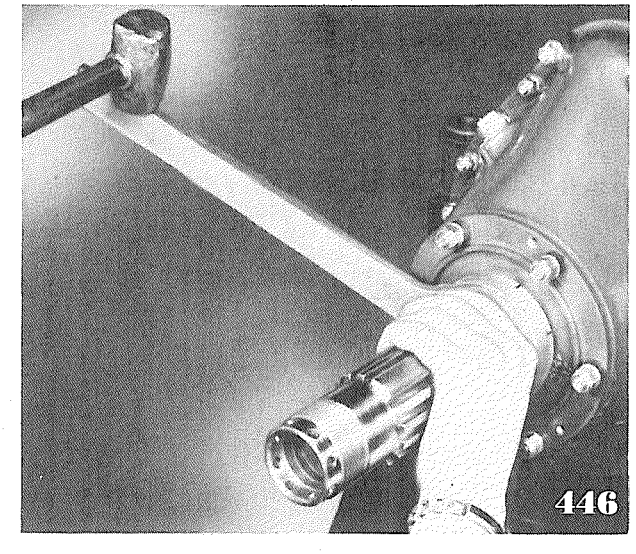
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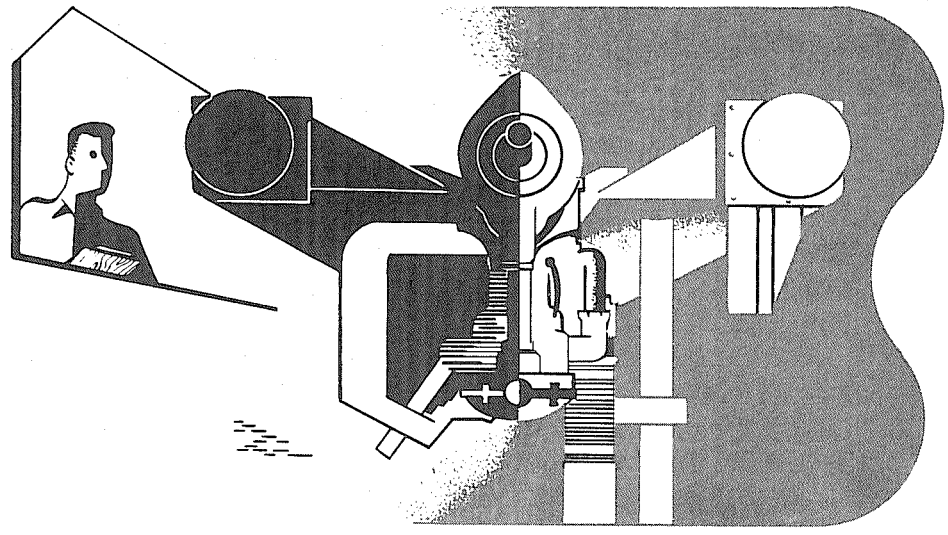
CHAPTER VI



RUN-IN OF ENGINE AFTER OVERHAUL

An overhauled engine must be run-in before it is ready for service. There are two reasons for this run-in.

1. Any newly installed parts, such as piston rings, bearings, etc., must be lapped or seated before the engine can be operated at high power output.
2. The operation of the engine must be observed through the entire speed range to determine whether it is running satisfactorily.

TEST STAND

As the method of running in of the engine may have a definite effect on the operating characteristics of the engine, the run-in should be carried out under closely controlled conditions on a specially designed test stand. This test stand must provide means for mounting the engine with all accessories. It should contain complete oil, fuel and electrical systems and should be equipped with all necessary gages and instruments to measure the output and performance of the engine. Although these various systems are closely related, they have been described and illustrated separately in order to simplify the description.

Engine Stand

The engine should be supported on a specially designed stand. This stand may be made of heavy gage angle irons or eye beams bolted or welded together and set into heavy concrete blocks. The stand should be braced so that deflection due to load or vibration is held to an absolute minimum. The engine should be supported on the stand by means of the standard engine mounting brackets which incorporate flexible bushings. Drawings of suitable designs for engine test stands can be supplied by the manufacturer.

Provisions should be made for attaching a hoist over the test stand. A monorail is preferable because it makes it possible to pick up the engine adjacent to the stand, move it over the stand and lower it into position Where an enclosed test cell is used, the height of the engine stand must be such that the center line of the propeller shaft coincides with the center line of the test cell.

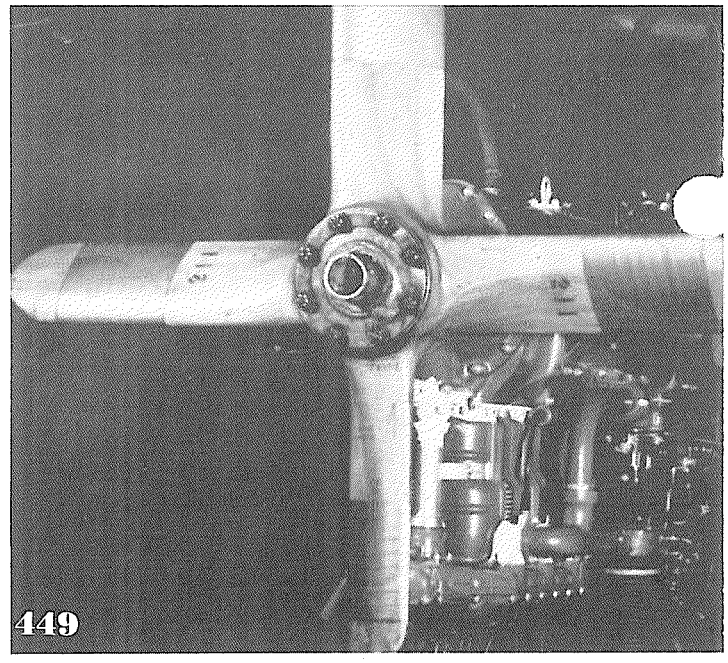
Test Clubs

The functions of the propeller during a test run are to absorb the power produced by the engine and to cool the engine. Both of these functions are different from those of a regular flight propeller and for this reason it is not advisable to try to use a flight propeller to run in an engine on the test stand. Instead, a specially calibrated test club should be used. The four bladed type of wooden test club is to be preferred 449

Suitable types of test club and propeller hub models are listed in the Tool Catalog.

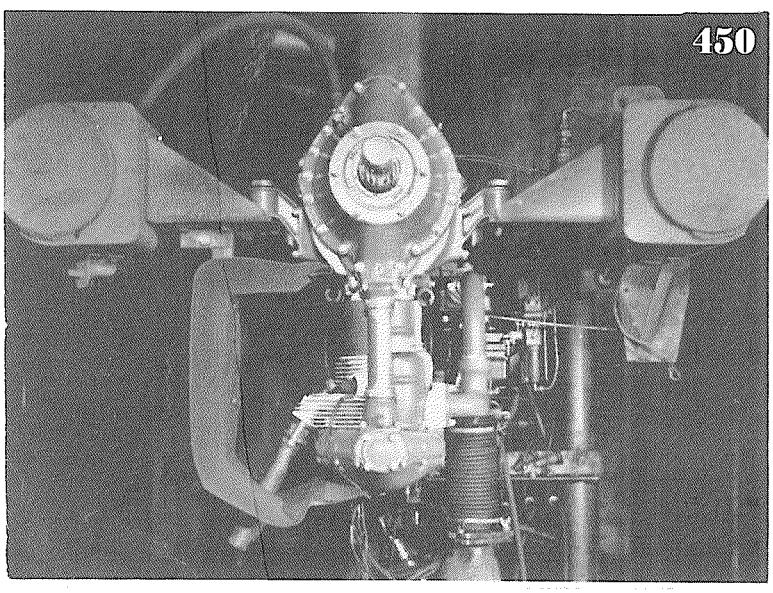
Test clubs should be calibrated to give rated speed at full throttle. The size of test club required to achieve this varies due to differences in altitude or climatic conditions at different overhaul stations and due to slight manufacturing variations of the test clubs. The diameter of four bladed test clubs for the 6-440C engines varies from 47 to 49 inches. In order to allow for these differences, new test clubs are made oversize, which will prevent the engine from running at rated speed when running at full throttle. As this would be harmful, any new propeller must be trimmed to the correct size before being used for a test run.

To calibrate a new test club, install it on a propellor hub and balance the assembly using conventional propeller balancing equipment. Then install the test club on a new engine or one which is known to give full power. Gradually run the engine up to full throttle to determine how much the propeller slows down the engine. Cut about an inch off each blade tip, rebalance and



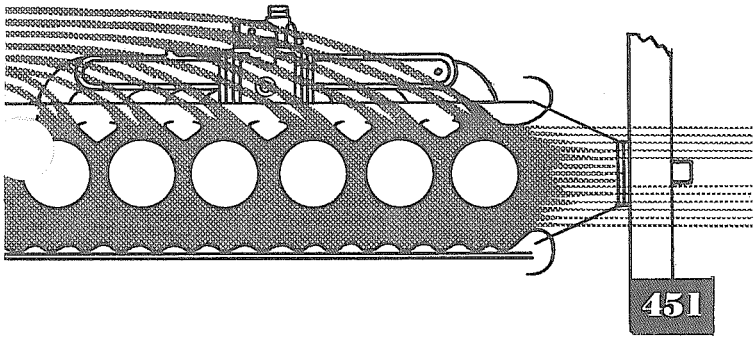
run the engine again. This will give an idea of about how much more the blades have to be cut to obtain rated speed at full throttle. When the calibration has been completed, sand off all sharp corners, varnish the propeller blade ends and again balance the test club.

This calibration should be carried out on a day when atmospheric pressure and temperature represent average conditions for the particular locality. The speed of the engine with a fixed test club will vary with temperature and pressure changes and where only one test club is available it should, therefore, be calibrated under average weather conditions. In localities where temperature variations are so wide that rated manifold pressure and speed cannot be held within the required limits of $\pm 2\%$ by using a single test club, two test clubs may have to be used, one for summer operation and one for winter operation.



Cooling Air Scoop

It is impossible to cool an air-cooled inline engine, such as the 6-440C by a direct and uncontrolled air blast from the propeller. If this is attempted, the rear cylinders will overheat after a comparatively short running period and may eventually cause piston seizure. Adequate cooling can be provided by installing a cooling scoop which fits tightly against the right side of the cylinders 450



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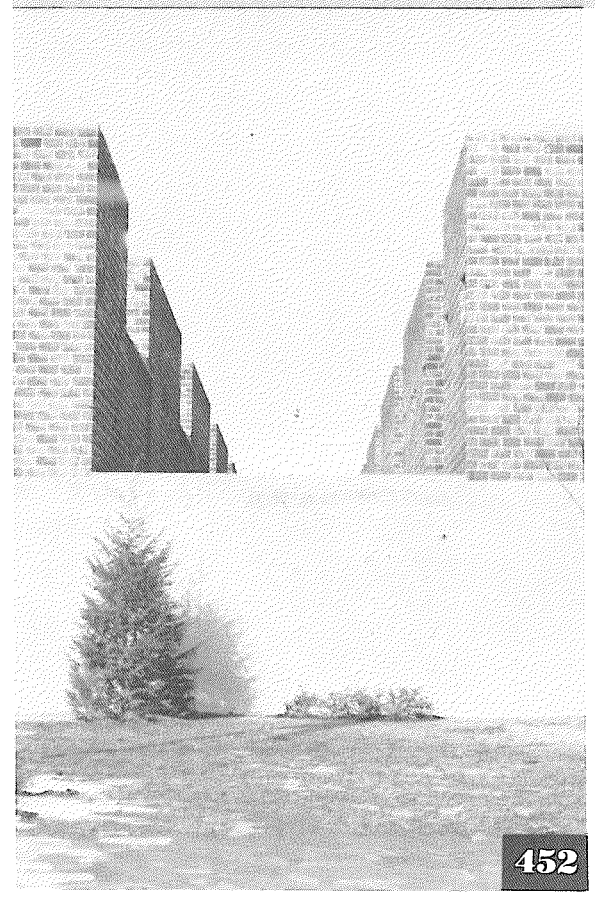
The air blast created by the test club will blow air into the scoop and will build up air pressure in it. This air pressure will tend to escape between the cylinders and will, at the same time, cool the cylinders by passing over the cylinder cooling fins. With the installation just described, the air in the air scoop can escape through the gaps between the cylinders so fast that air pressure in the air scoop may not build up sufficiently and consequently cooling will be insufficient. To counteract this, inter-cylinder baffles are installed which reduce the gap between the cylinders and at the same time guide the cooling air around the back of the cylinders 451

This shows how important it is to see that all baffles and a suitable air scoop are installed before starting the test run. The baffles are standard equipment on all engines. Suitable designs for test stand air scoops can be supplied by the manufacturer. Where a test scoop of this type is not readily available, the air scoop out of the airplane in which the engine is to be installed may be used. The exact shape of the air scoop is not as important as the fact that it should fit tightly around the edges so that there are no leaks between the scoop and the engine. All baffles must also fit tightly.

Enclosed Test Cells

Under favorable climatic conditions or where an engine stand is to be used only infrequently, it may be sufficient to merely provide a roof directly over the engine stand. However, where large numbers of engines are to be tested after overhaul and where the stand has to be built close to the overhaul shop or other buildings, a completely enclosed and sound proofed test stand is desirable. The use of such a stand



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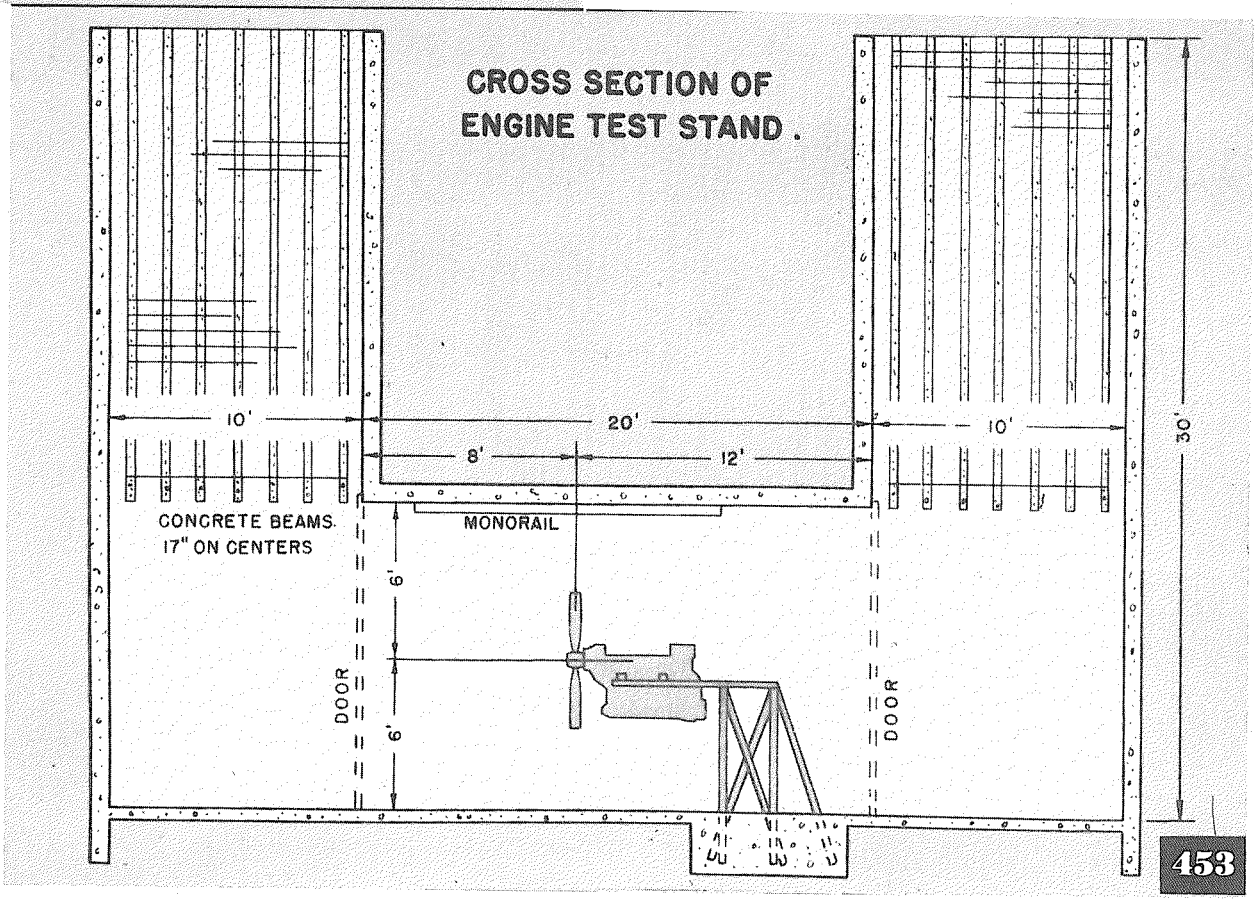
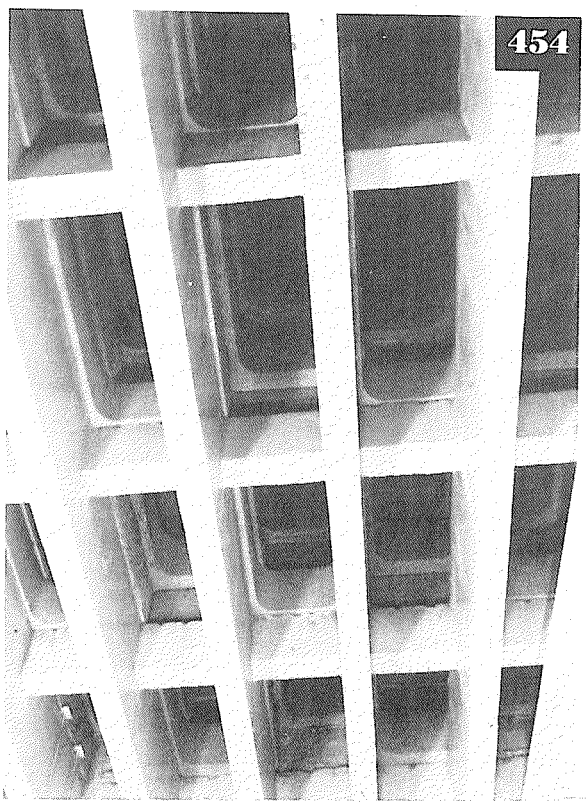
will improve working efficiency because it can be used in all kinds of weather and because the absence of noise during actual tests reduces fatigue of the operator.

An enclosed test stand consists of the test cell proper which houses the engine on the engine stand and is open at both ends, and of two vertical shafts at either end which are of approximately the same cross section as the test cell and which serve to carry the air into and away from the test cell...452

The ideal shape of the entire test house would be to have the towers and the cell of circular cross section and to have the vertical sections turning into the horizontal section in a large smooth radius. Since such a test stand is difficult and expensive to build, a test stand of square cross section is the best compromise. In order to eliminate interference from the flat wall sections and sharp corners, the height and width of the horizontal section which houses the engine should be at least twice the diameter of the test club. The test club for the 6-440C engines has a diameter of a little over 4′ and the test cell should, therefore, be 10′ high



and 10′ wide. The length of the test cell should be approximately 20′. The engine should be so mounted that the propeller disc is located approximately the same distance from either end. The upright air inlet and outlet stacks should be of approximately the same cross section as the horizontal portion.....**453**



Doors should be provided between the test cell and the stacks, which can be closed while the engine is being installed on the stand. These doors must fit into recesses in the walls or ceiling when fully open so that they will not interfere with the smooth air flow through the test cell.

To be sound proof, the walls of such a test stand should be of concrete or of hollow cinder blocks. The stacks should be about 30′ high and should be fitted with an air straightener and silencer, running the entire length of the stack and dividing it into 12″ squares.....**454**

Since most engines are equipped with tractor propellers, the door leading into the test stand should be behind the engine so that there is no chance of a mechanic being drawn into the revolving propeller when the engine is running. The door should be hinged on the side from which the propeller blast comes so that there is a tendency to blow the door shut instead of open. The door itself should be of sound proof and fire proof material. An inspection window 2′ x 4′ should be installed in the wall of the

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test stand, approximately opposite the engine. This window should have double thicknesses of glass mounted in felt for sound proofing. In order to guard against damage from propeller failure, the walls of the test stand should be reinforced with ½″ boiler plate extending about 2′ on either side of the plane of the propeller disc. Flood lights should be installed in the walls on both sides of the engine so that the engine is fully illuminated at all times during the installation and test run.

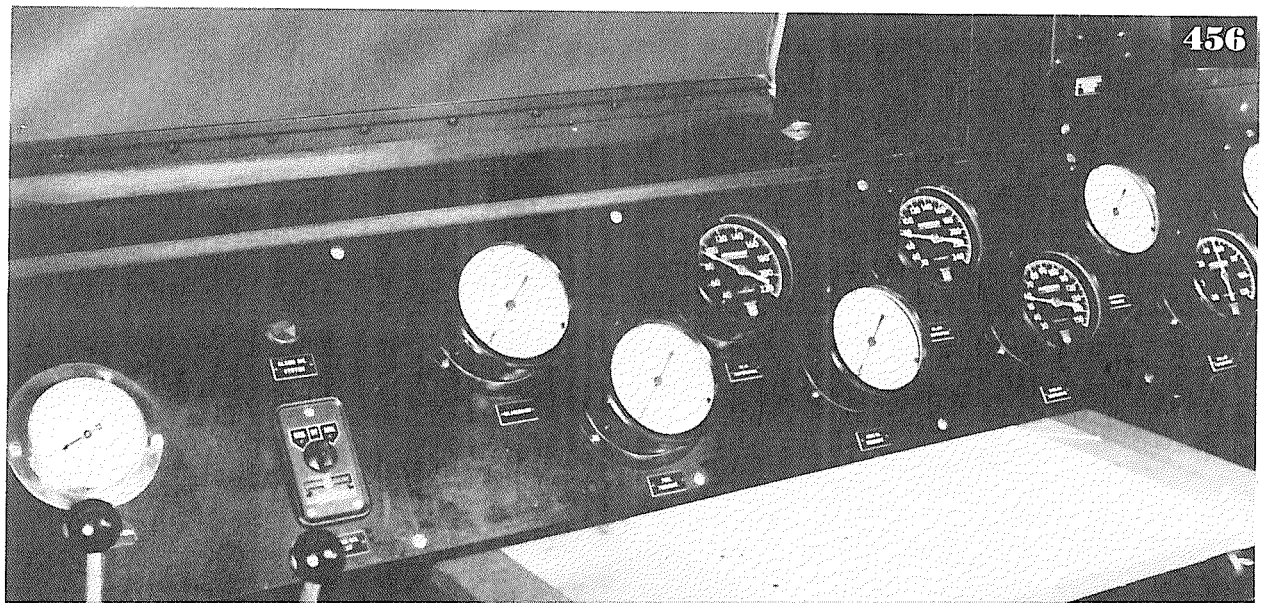
An automatic fire extinguishing system trained on the engine and the fuel and oil connections is desirable.

Control Room

The control room is located adjacent to the test cell and houses all the necessary equipment which of necessity cannot be installed in the stand itself.....**455**

10′ x 20′ is considered an adequate size. The observer's desk should be mounted immediately below the observation window with its surface about 3′ above the floor.....**456**

The desk carries the major engine controls such as throttle, mixture and carburetor heat levers and also provides writing space where the engine log sheet can be filled in. The instrument board should be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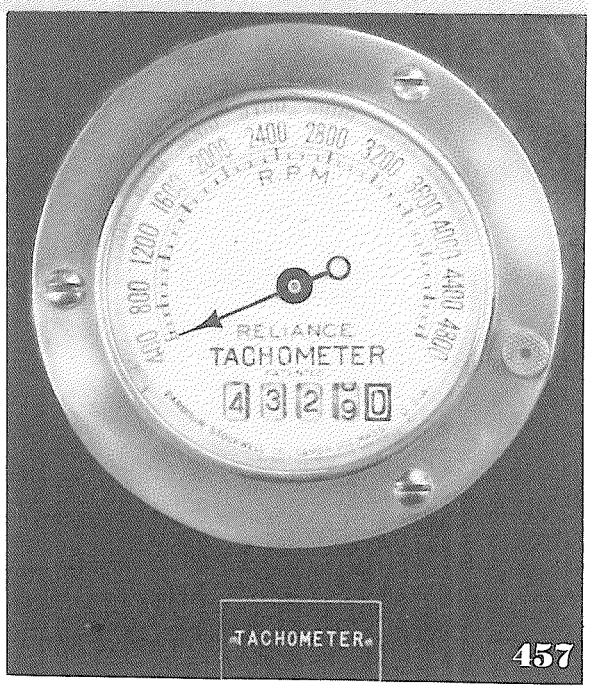

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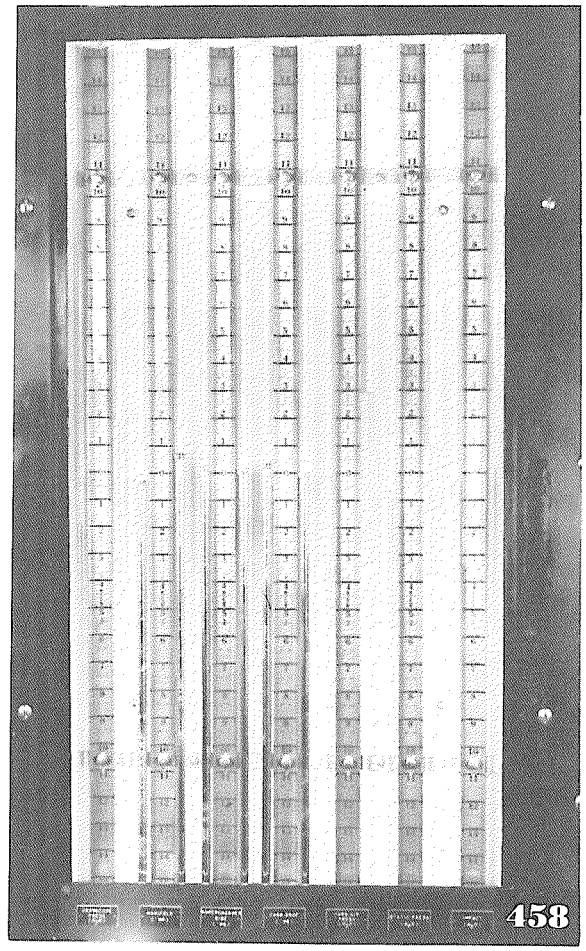
located immediately above the desk. Most of the instruments required may be standard aircraft flight instruments. However, the revolution indicator should be equipped with a revolution counter which can be started and stopped manually.....**457**
Manometers may be made from glass "U" tubes filled with mercury or water and calibrated in inches.....**458**
A clock and stop watch are also required. Controls and instruments which cannot be mounted on the board or the desk should be grouped on either side of the desk as close as possible and in the most convenient position for the operator.....**459**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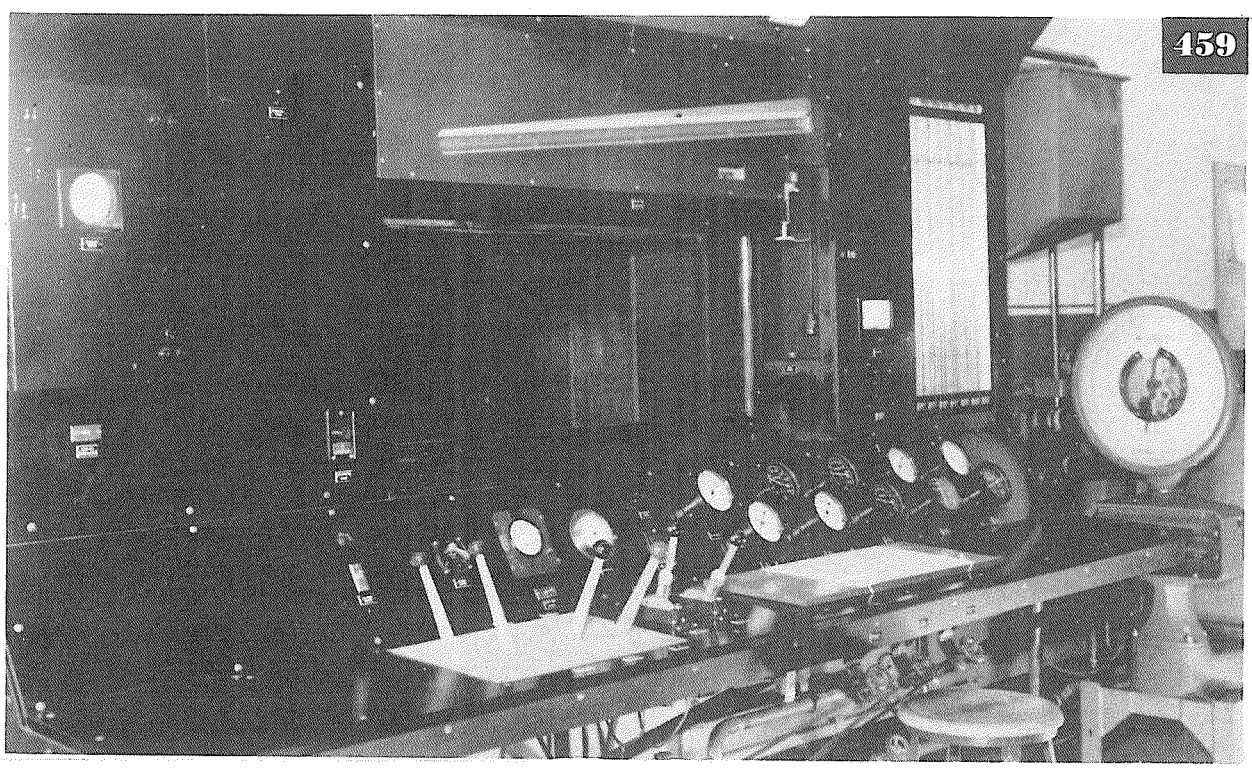
It must be remembered that the run-in of the engine involves considerable responsibility and that some of the tests have to be carried out with great speed to be accurate. Therefore, the operator should be relieved of all distracting influences such as would be caused by a test stand which is improperly laid out. The use of electrical pressure warning units is recommended.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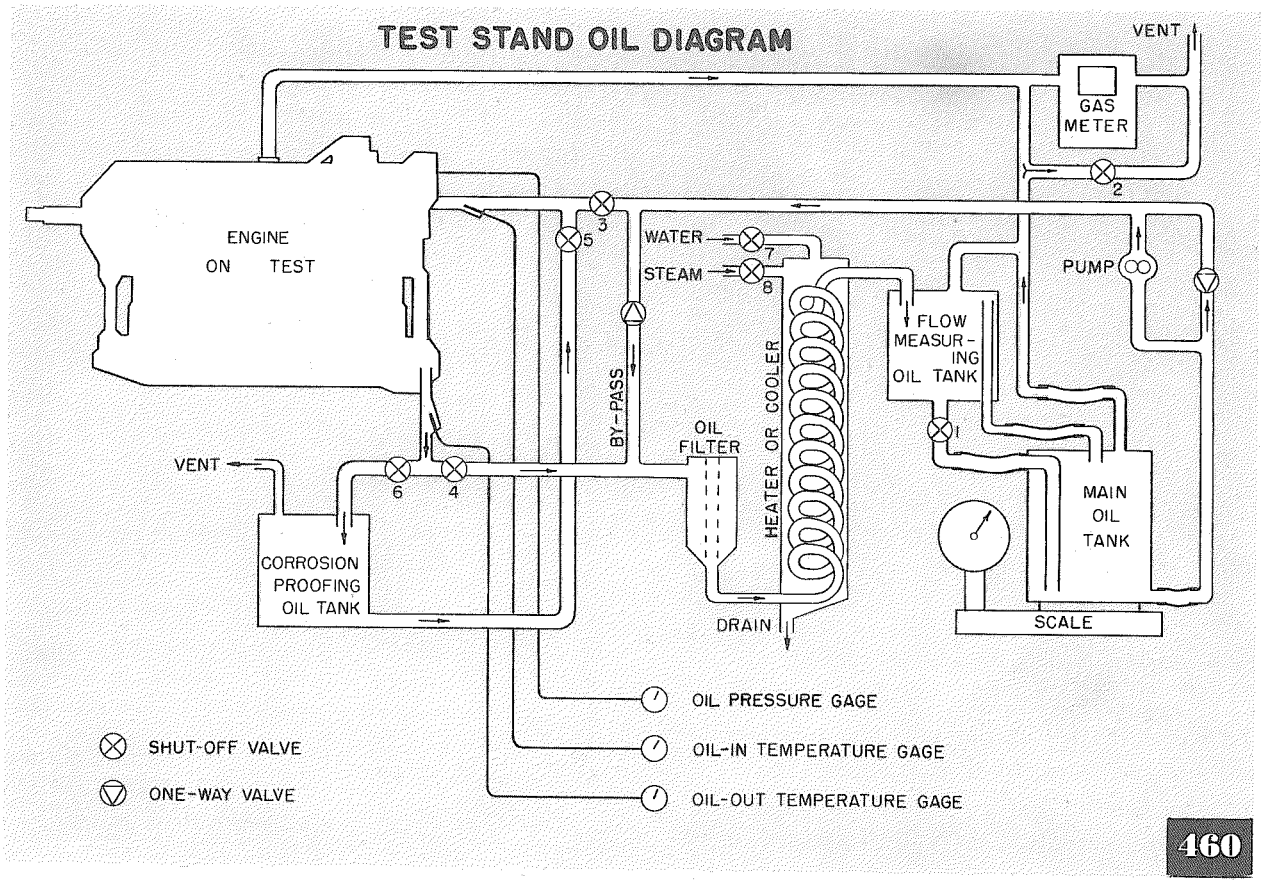

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Oil System

The test stand oil system differs from an airplane oil system in that it has facilities for pre-heating and circulating the oil as well as for measuring for consumption oil flow and blow-by.....**460** The main oil tank is mounted on a scale which provides an accurate check of the quantity of oil in the tank at all times.**461** In order not to impede the movement of the scale platform, all connections to and from the tank have to be made with horizontal flexible tubes of sufficient length to allow complete freedom of movement of the scale platform. From the main oil tank, the oil is fed to the engine through the main oil supply line. The temperature of the oil is measured just before it enters the engine and this temperature registers on a temperature gage on the instrument board. The temperature of the oil coming out of the engine is measured as close to the engine as possible and registers on an oil temperature gage. The oil is then returned through the

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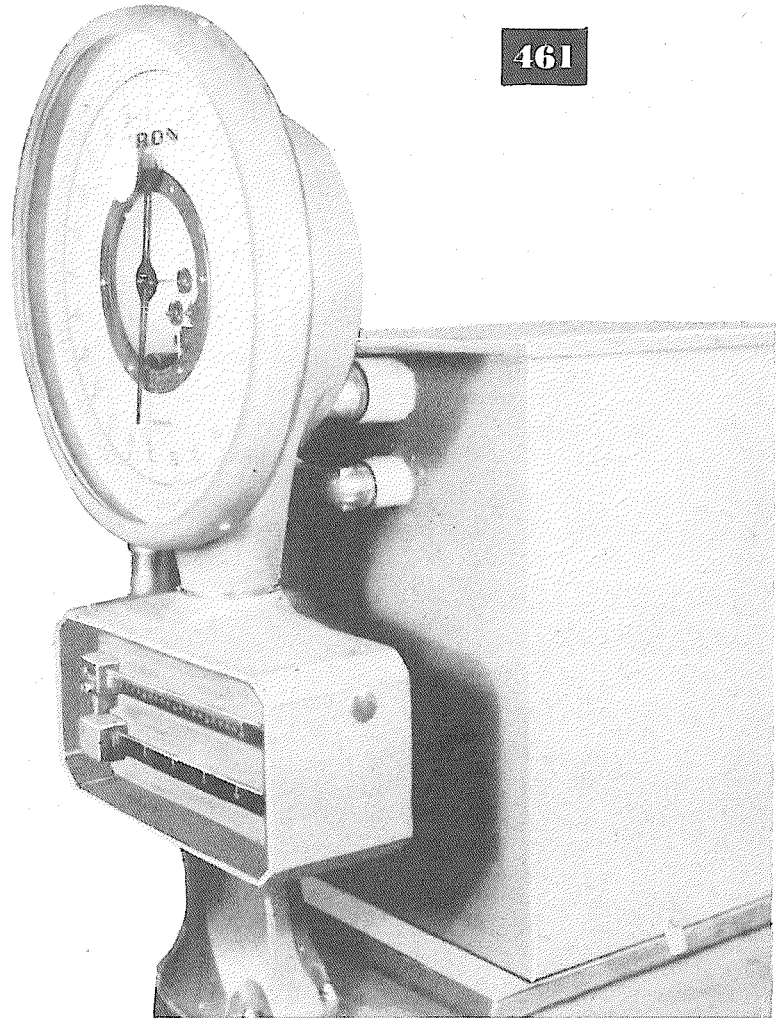
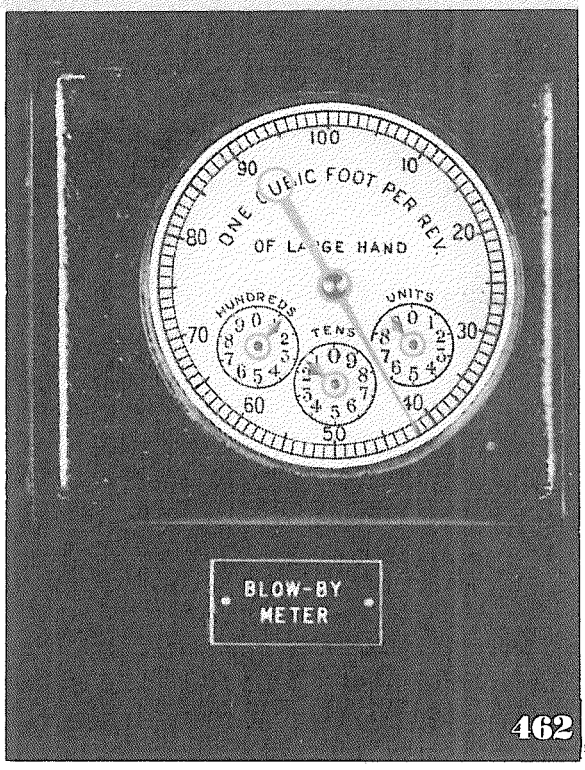




oil filter, the oil cooler and the flow measuring oil tank to the main supply tank.

In order to heat the oil to the minimum operating temperature of 60°C. before starting the engine, the oil should be circulated by a pump connected parallel to the main oil supply line. By shutting off valves 3 and 4 on the oil diagram, the oil will by-pass the engine and return to the tank through the filter and cooler. The cooler consists of a coil in a tank through which cold water can be circulated. When it is desired to heat the oil before starting, the water is turned off and live steam is passed through the tank, which heats up the oil as it passes through the coil. After the engine is started, the circulating pump is stopped and acts as its own shut-off valve. The oil then flows through the one way valve in the main oil supply line and through valve 3, which is now open, into the engine. Valve 4 must be opened at the same time so that the oil can return to the tank. Since the pressure pump maintains suction in the supply line and the scavenge pump maintains pressure in the return line, the one-way valve in the by-pass line will prevent any oil from by-passing the engine. The actual operation of the oil system is more fully described as part of the actual test procedure.

The volume of combustion gases which passes by the piston rings and into the crankcase is an indication of the degree to which the piston rings have seated. The volume of these crankcase gases can be measured by connecting the engine breather to a standard domestic gas meter . . . **462** Some of the fumes will leave the engine as bubbles in the lubricating oil instead of through the breather and, therefore, the entire oil system should be sealed and should be vented only through the gas meter. As it is only necessary to measure the blow-by at intervals, a by-pass is provided which allows crankcase gases to by-pass the meter when no readings are being taken. The breather outlet should be in the test cell and not in the control room to prevent accumulation of harmful gases. However, the outlet should be within sight of the operator as it may be of importance to note whether the breather outlet fumes are smoky.

An entirely separate oil tank without the various test devices is provided, so that the engine can be run on corrosion preventive oil after the regular test run has been completed. This procedure is more fully described in Chapter VII.

During the test run, engine oil pressure is checked by connecting a pressure gage to the standard oil pressure connection at the pressure oil pump.

Fuel System and Carburetor Connections

The test stand fuel system is similar to that used in the airplane except that provision is made for accurately measuring fuel consumption **463**

Fuel of the octane rating specified for the engine on test is drawn from a tank, which is normally buried underground, by means of an electrically driven fuel pump. The fuel passes through a pressure regulating valve and is then delivered to the engine driven fuel pump mounted at the rear of the scavenge oil pump. From the fuel pump, the fuel passes to the carburetor. The fuel pressure gage is connected to the prop-

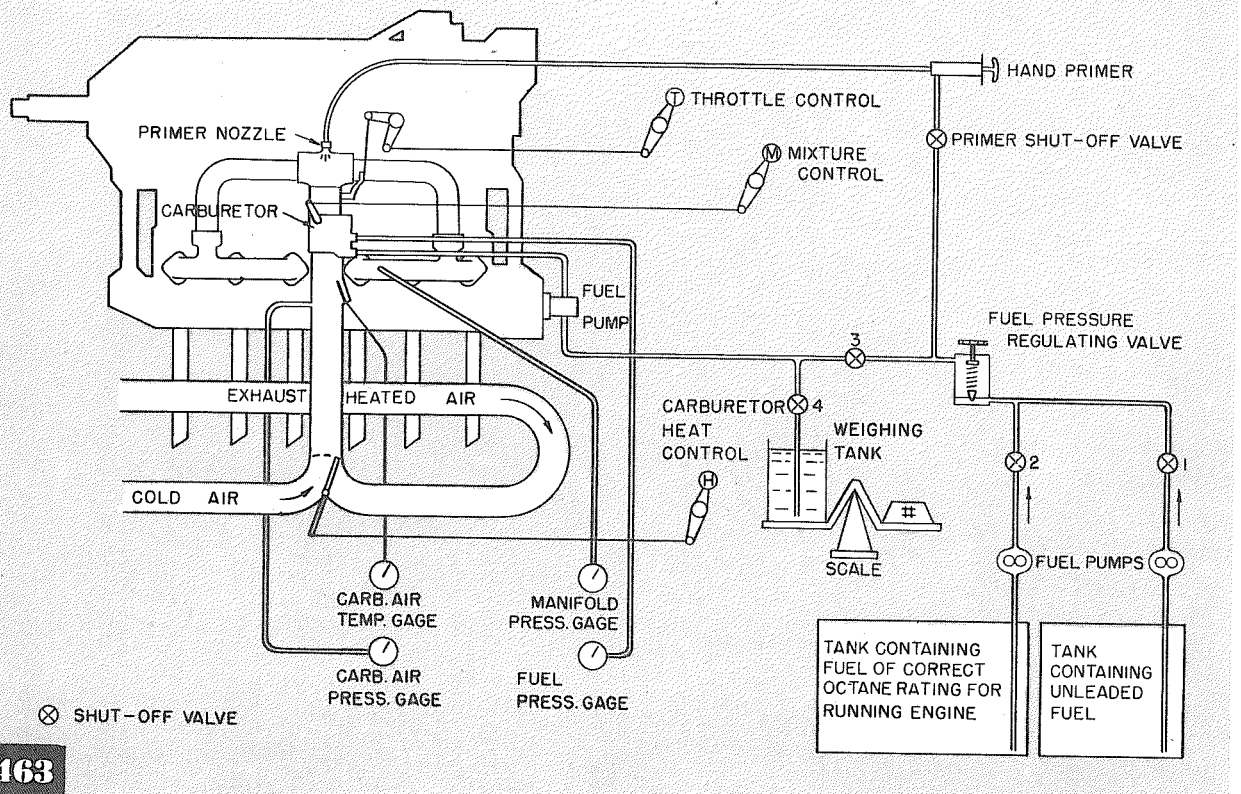
er outlet on the carburetor in the same way as it is in the airplane installation.

Throttle and mixture controls are connected to levers on the observer's desk through push-pull rods and bell cranks. The link of these controls should be so designed so that the travel of the levers at the observer's desk is greater than that required by the carburetor controls.

A fuel weighing tank mounted on a scale is connected into the main fuel line. To fill the tank, valve 4 on the fuel diagram should be opened. When the tank is full, valve 4 should be left open and valve 3 should be closed. The fuel will now be drawn entirely from the measuring tank and the time necessary to use up a certain weight of fuel on the scale can be checked with a stop watch. This procedure is more fully explained later. At the end of the test run, the engine is usually run on unleaded gasoline to clear any lead deposits out of the engine. This is done by closing valve 2 and opening valve 1 on the diagram. This procedure is more fully explained in Chapter VII.

Provisions should be made against excessively low carburetor air temperature by providing some means of heating the air drawn into the carburetor. The installation in the airplane may be duplicated for use in the test stand. In order to control the temperature of the carburetor air, a two-way valve, which will admit either cold or heated air, or a mixture of both, is located in the carburetor air intake pipe and is connected to a control lever on the control desk. A temperature bulb in the intake pipe located as close to the carburetor as possible measures the temperature of the carburetor air, which registers on a temperature gage on the instrument board. A pressure tube is connected to the air intake pipe near the carburetor and measures carburetor air pressure which registers on a "U" tube filled with water on the instrument board and is recorded in units of inches of water.

DIAGRAM OF TEST STAND FUEL SYSTEM AND CARBURETOR CONNECTIONS.



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Electrical Connections

The diagram shows all electrical test stand connections, even though some of them are not necessarily related.....464 Only the magneto and starter have to be installed to test run the engine, but it is preferable to install as many accessories as possible so as to properly test the accessory drives. If a generator is installed, it must be connected properly or it will burn itself out. In most cases, it can be used to advantage to recharge the battery used for starting the engine. The generator shown on the diagram is a shunt-wound, 2 pole type. Other types of generators may require slightly different connections. The starter shown on the diagram is the direct cranking electrical type. An ammeter and volt meter are incorporated in the system so that the proper operation of the generator can be checked.

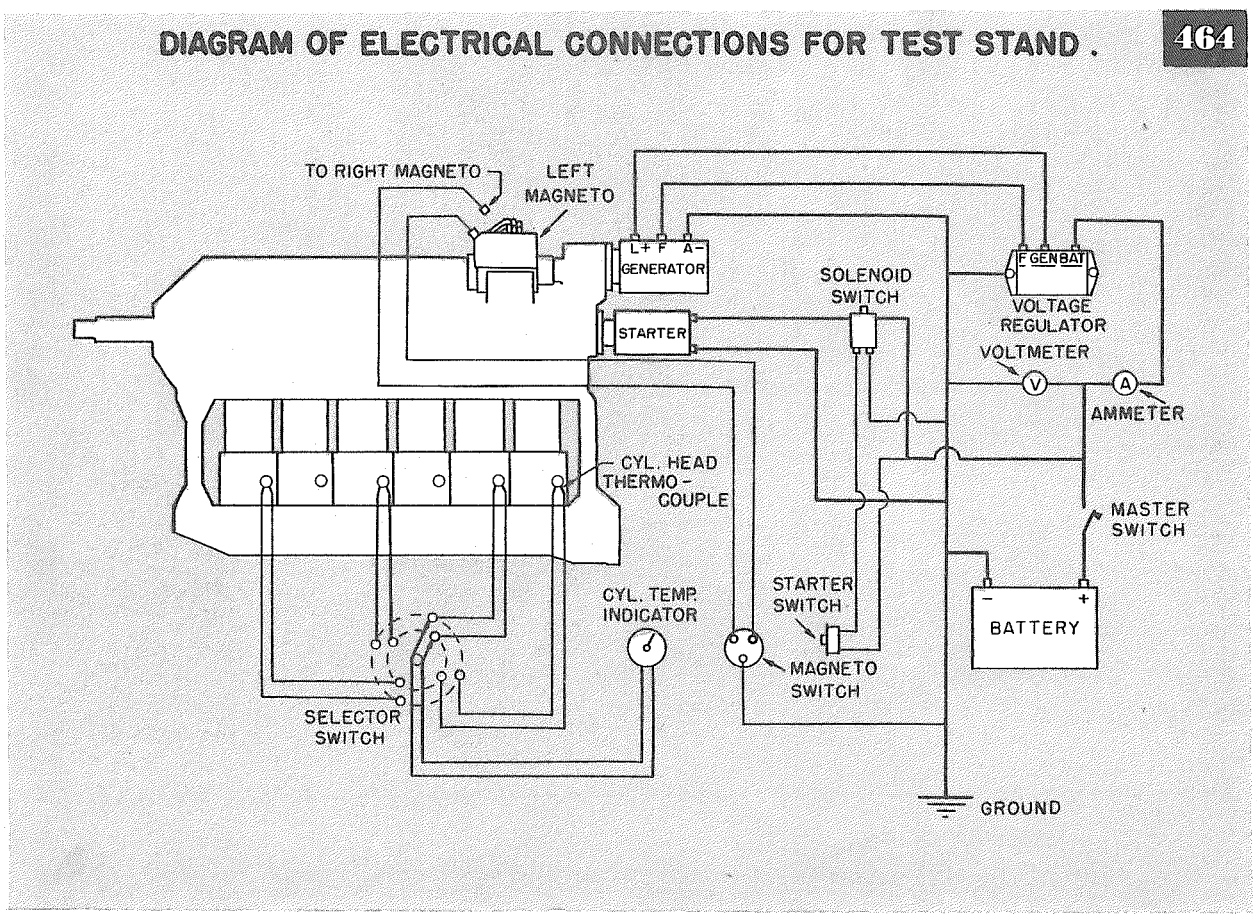
The two magneto ground terminals at the upper forward end of each magneto are connected to the terminals of a standard aircraft type magneto switch. The lead from the ground connection on this switch should be run back into the test stand and should be grounded on some part of the engine.

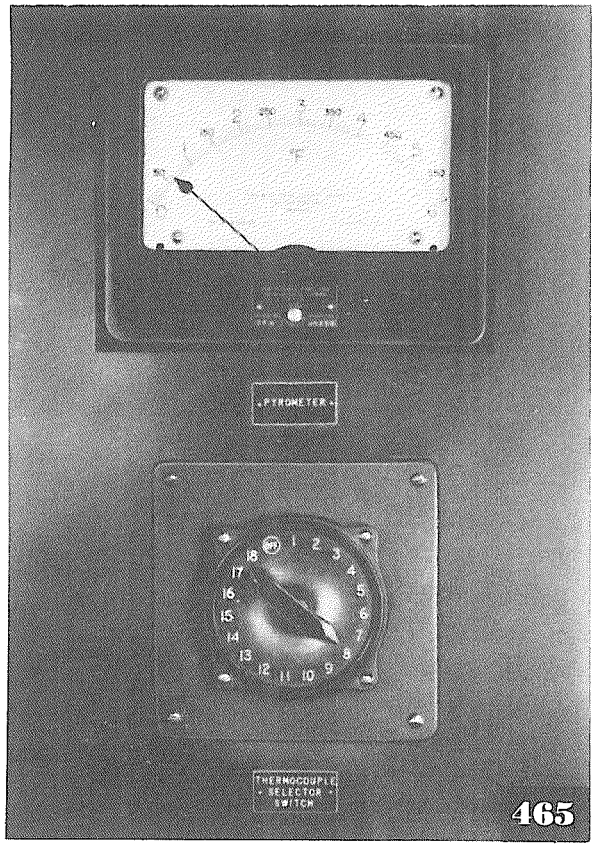
Thermocouples are essential to check cylinder head temperatures during the test run. Two or three thermocouples will normally be sufficient. The thermocouples should be installed in those locations which experience shows will normally run hottest. All thermocouples are connected to a selector switch on the observer's desk.....465 The various positions of the selector switch should be identified with the location of the particular thermocouple on the engine so that the temperature at any point can be shown on the cylinder temperature gage by turning the handle of the selector switch.

RUN-IN OF ENGINE IN AIRPLANE

Running in of the engine in the airplane is not normally recommended because it is impossible to accurately control the running conditions or to measure the fuel and oil consumption of the engine in the average airplane installation. There may, however, be cases where a suitable test stand is not readily available and in this case, the engine can be run-in in the airplane provided certain precautions are observed.

The engine and all accessories should be installed and connected in the usual manner. The cowling air scoop and all baffles, the carburetor air intake scoop and the ex-





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haust pipes must be installed. All outer cowlings should be left off, except in very cold climates where the outer cowlings are necessary to keep the engine at operating temperature. The nose cowl may, however, be installed if it acts as a support for the air scoop or other parts of the installation.

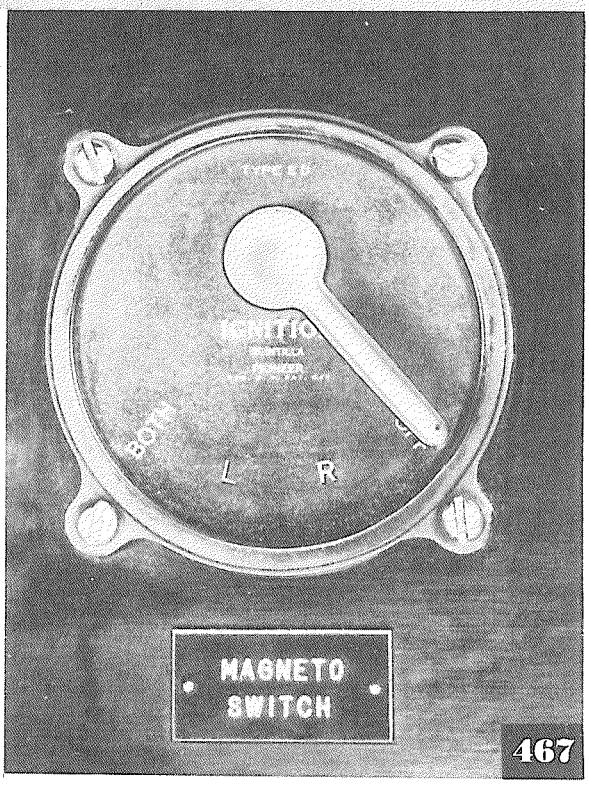
A four bladed test club should be installed instead of the flight propeller to avoid the possibility of overheating due to a reduction in the volume of air forced into the air scoop.

It is preferable to warm up the oil just before pouring it into the oil tank. The engine should then be turned over by hand until the oil pressure just registers on the gage. The oil tank should be full before the engine is started.

Head the airplane directly into the wind to obtain the maximum cooling effect. If the wind direction changes during the test run, the position of the airplane should also be changed. The airplane should be placed in such a position that the slipstream will not blow towards buildings or towards other airplanes. The wheels should be chocked and the tail should be tied down if necessary.

After the engine has run for a few minutes, it should be stopped and the oil tank should again be filled up. The reason for this is that under normal running conditions, a certain quantity of oil stays in the engine at all times. Since the engine was dry when it was installed, this minimum quantity of oil will immediately be drawn from the tank. Since oil consumption is likely to be higher during the first few hours of run-in, than during subsequent operation, it is important to see that the oil tank is completely filled before starting the actual test run.

The engine should be operated on the same schedule of running periods and engine speeds as for the regular run-in on a test stand. However, it should not be run at power outputs above 90% and should be run at 90% power only long enough to check the proper functioning of the engine (approximately 5 minutes). After the run-in of the engine, the test club should be removed, the flight propeller and all engine cowlings should be installed, fuel and oil supply should be checked and the plane made ready for flight. The plane should be taken off and be cruised at 90% power for about three hours. During this time, a close check of the engine instruments should be maintained. At the end of this period, the performance of the engine may be checked at full power..... 466



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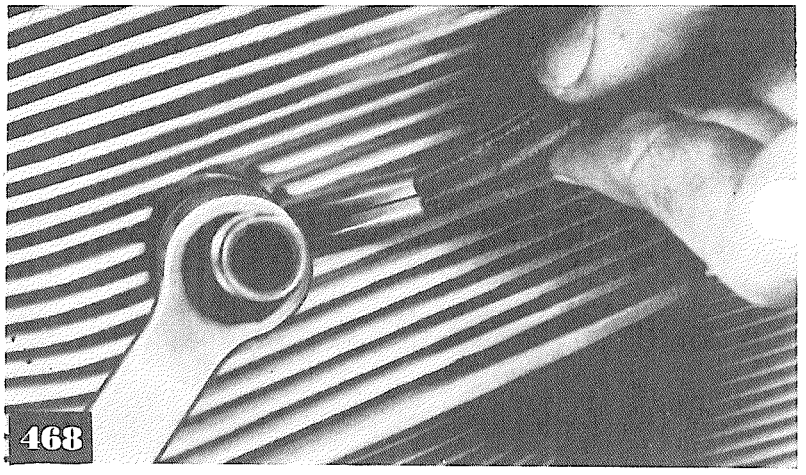
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INSTALLING ENGINE ON TEST STAND

After overhaul, the engine on the engine assembly stand should be wheeled into the test stand and under the chain hoist. Attach the engine to the chain hoist by inserting the hook of the hoist into the lifting eye on top of the crankcase. After the slack in the hoist has been taken up, the bolts holding the engine to the assembly stand can be taken out. After this, the engine should be lifted to the level of the engine bearers of the test stand and then pushed back on the monorail so that the mounting brackets on the engine are directly in line with the engine mounting holes on the test stand.

During this transfer, the engine should be guided by one man on each side to avoid the possibility of damage to the intake pipes, ignition manifolds or other parts of the engine by striking against the test stand. Lower the engine into position and install and safety the mounting bolts. After the engine is secured to the test stand, the chain hoist can be removed. The chain hoist must be either taken off the monorail or the chains must be secured so that they cannot move in the slipstream. The magneto ground wires should be installed immediately after the engine is installed. The magneto switch should be checked at the same time to see that it is in the "Off" position 467

Install the exhaust stacks and the carburetor air duct. Install the carburetor air temperature gage bulb in the duct and connect the carburetor heat control valve to the lever in the control room. A carburetor air pressure gage should be installed if necessary. Connect the main fuel line to the fuel pump on the engine, connect the fuel pump to the carburetor and connect the fuel pressure connection at the carburetor.

Install the air scoop and see that it is properly braced so that it will not work loose during the test run. See that the scoop fits tightly everywhere, especially where it connects with the rear baffle on the engine. Remove the pipe plug from the breather opening and connect the breather pipe.

Connect the manifold pressure gage line to the manifold pressure gage connection at the intake manifold. Such a connection is provided on both manifolds, but only one manifold need normally be connected. Remove the starter replacement cover and install the starter. Connect the oil supply line at the pressure oil pump. Connect the oil outlet line at one of the two oil outlet lines at the rear of the camshaft housing. Connect the oil pressure gage line at the rear of the oil pressure pump and connect the oil temperature bulb at the threaded hole in the center of the oil filter cover.

If the starter is of the electrical type, connect the starter cables to the terminal posts on the starter.

Remove the generator replacement cover and install the generator. Connect the generator to the voltage regulator in accord-

ance with the generator manufacturer's recommendations.

Install washer type thermocouples under three or four spark plugs. When tightening the spark plugs hold the thermocouple wires in the grooves provided for this purpose to prevent damaging them. 468
Cylinder temperature should be checked on those cylinders which experience has shown to run hottest. The intake spark plugs of the forward cylinders normally run hottest, but this condition may vary with each installation and will, therefore, have to be determined individually for each test stand. The thermocouple wires should be connected to the selector switch at the observer's desk and the location of the various thermocouples should be marked at the switch.

Lubricate the propeller shaft with engine oil or castor oil. Install the propeller spacer, rear cone and propeller with hub. Place the two halves of the split front cone on the propeller nut and install both parts together. Use a bar or wrench about 4′ long to tighten the propeller nut and safety the nut. 469
Turn the propeller by hand through about 6 revolutions in the normal direction of rotation in order to clear out any oil which may have accumulated in the combustion chambers. If the propeller is very hard to turn, it may mean that enough oil has accumulated to prevent a piston from reaching top center. In this case, do not attempt to force the propeller as this may bend a connecting rod. Instead, take out the exhaust spark plugs and let the oil drain from the cylinders.

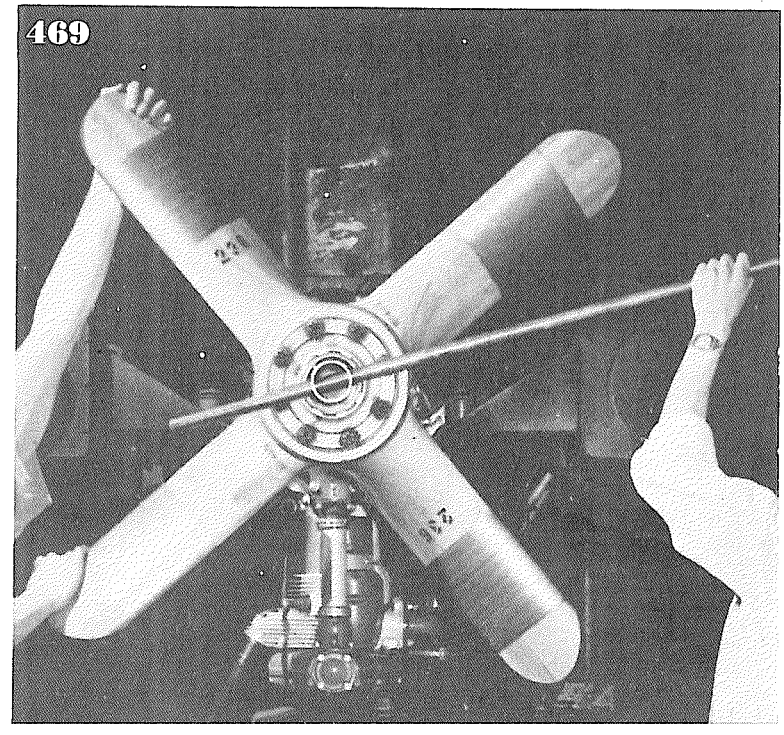
After the installation has been completed, the entire engine installation should be inspected. Check all fuel and oil connections for tightness. Turn on the fuel pump and oil pump so that the systems are under pressure and check for leaks. See that the main oil tank contains a minimum of 30 pounds of oil. When reading the quantity of oil on the scale, do not forget to subtract the dead weight of the oil tank and connections. Check each individual thermocouple to see whether it is connected properly. A properly connected thermocouple will indicate the temperature of the test cell whereas a thermocouple which has become disconnected will indicate zero. All loose wires such as magneto ground wires and thermocouple wires should be taped securely to some part of the test stand so that they cannot vibrate. These wires should not be taped to the engine itself because even slight vibrations may cause wear at the point where the wires touch the engine. This is particularly dangerous in the case of the thin walled intake pipes.

Move the engine assembly stand out of the test cell and carefully check the entire test cell to see that no loose tools or equipment are left lying in the test cell. When the engine test cell has been cleared and the engine is ready to start, the doors at each end of the test cell should be opened.

STARTING THE ENGINE

Before the engine can be started, the oil must be warmed up to operating temperature. In order to do this, valves 3, 4, 5, 6, and 7 on the oil diagram should be closed. Valves 1, 2 and 8 should be opened. Start the oil circulating pump and let it run until the oil-in temperature reached 60°C.

While waiting for the oil to warm up, the overhaul test log sheet should be made ready. A copy of this form may be found in Chapter VIII.



The model and serial number of the engine and all accessories should be entered on the sheet as well as the test club model and the grade of fuel and oil used. The location of the various thermocouples should also be marked at the head of columns 18 to 22.

When the oil has been warmed to the proper temperature, shut off the oil pump, open valves 3 and 4 and shut valve 8. Make sure that the engine is still switched off, then enter the test cell and turn the propeller by hand until oil pressure starts registering on the oil pressure gage. Start the motor driven fuel pump and open valves 2 and 3 on the fuel system diagram. The mixture control should remain in the full rich position throughout the test run. It should only be used to work the fuel cut-off after the test has been completed.

To prime the engine, move the throttle lever back and forth three or four times. In extremely cold weather it may be neccessary to use a hand primer connected to a spray nozzle in the "T" connection immediately above the carburetor. The primer is most effective if it is operated just as the engine starts turning.

Place the master switch of the battery in the "On" position. Turn the ignition switch to "Left Magneto," press the starter button and at the same time carry out the priming instructions. As soon as the engine starts firing, turn magneto switch to "Both On". Immediately after the engine has started, watch the oil pressure gage carefully. If oil pressure does not register within 20 seconds, switch off immediately and investigate the reason.

Before starting the actual run-in, the engine should be allowed to warm up until all pressure and temperature readings have become stabilized and the amount of oil on the scale remains constant. The warm-up should be conducted at the lowest speed at which the engine will run smoothly, but not less than 800 RPM. If during this warm-up period it is found that the oil pressure is less than the permissible minimum, it should be adjusted before starting the test run proper. To do this, enter the test cell and, with the engine still running at high idling speed, remove the oil pressure relief valve cap. Loosen the oil pressure relief valve locknut with a wrench and use a screw driver to screw the relief valve in if the pressure has to be raised or back it off if the pressure should be lowered. This operation is best carried out by two men, one making the adjustment on the engine while the other one signals from his position at the instrument board to let the mechanic know when the pressure is set correctly. After this, the locknut should again be tightened and the protective cap should be installed and safetied.

TEST RUN OF ENGINE

The success or failure of the entire engine overhaul may depend on the care with which the run-in is carried out. In order to satisfactorily complete the test, the following rules must be observed.

1. Follow the test schedule given below. This schedule has been established as the result of exhaustive tests and any changes, especially the shortening of the run-in period, will have an adverse effect on the condition of the engine after the run-in period.

2. Keep all engine operating conditions within the limits specified below. Some of these limits differ slightly from those given for subsequent flight operation. The reason for this is that greater care must be taken in running in the engine than is necessary after all parts have been thoroughly lapped and polished.

3. Observe the following safety precautions.

a. Keep a close check on the instruments at all times and note particularly any sudden changes in the readings for which there is no obvious reason. For instance, a gradual loss of oil pressure accompanied by an increase in the oil temperature may indicate that the oil filter has become clogged either with carbon or with foreign particles and damage to the engine can be avoided by cleaning and examining the filter before continuing the test run. A gradual decrease

in the engine speed during any one period may merely indicate that engine vibration is causing the throttle to creep. On the other hand, it may mean that the carburetor is icing up and this condition should immediately be remedied by the aplication of hot carburetor air or by the use of some approved deicing fluid which is sprayed into the carburetor air intake.

b. In addition to watching the instruments, the appearance of the engine itself should also be checked. Heavy oil leaks or loose parts can be readily detected by observing the engine through the observation window, long before the effect of these defects is indicated on the various engine gages.

c. If any abnormal condition is observed, the engine should be switched off immediately. Such quick action may prevent considerable damage to the engine.

Test Schedule

Length of Period, Mins.	Power Output	Eng. Speed RPM	Manifold Pressure "Hg.
15	—	1100	—
15	—	1400	—
20	—	1650	—
20	—	1800	—
20	—	1900	—
30	—	2050	—
30	—	2150	—
60*	—	2225	—
90*	90%	2275-2375	25.5-26"Hg.
30	Full Power	2400-2500	—

*Take readings every 30 minutes.

Operating Limits

Fuel Pressure.....2.5 to 3.5 lbs./sq. in.
Carburetor Air Temperature: Desired....80°F.
Maximum RPM drop on either Magneto.....50 RPM
Oil Flow at Rated Power at Oil-in Temperature of 165°F....25 to 35 lbs./sq. in.
Oil Consumption: Maximum. .025 lbs./HP hr.
Oil Pressure:
Maximum at Rated Power... 70 lbs./sq. in.
Minimum at Rated Power... 50 lbs./sq. in.
Minimum at Idling Speed (below 600 RPM)..... 15 lbs./sq. in.
Oil Temperature: Minimum .. 70°C.(160°F.)
Maximum .. 77°C.(170°F.)
Cylinder Head Temperature:
Maximum .....465°F.

Fuel Consumption:

Engine RPM	Fuel Flow in lbs./hr.	
	Min.	Max.
2450	107	116
2325	87.5	94.5
2225	72	78
2150	63	69
2050	57.5	62.5
1900	46	50

Blow-by:
No definite limits have been established as this is only a qualitative indication of the sealing effect of the piston rings.
Time to Stop Engine, Using Fuel Cut-off:
Maximum ..... 7 seconds
Time to Accelerate from Idling to Take-off Power: Maximum ..... 10 seconds

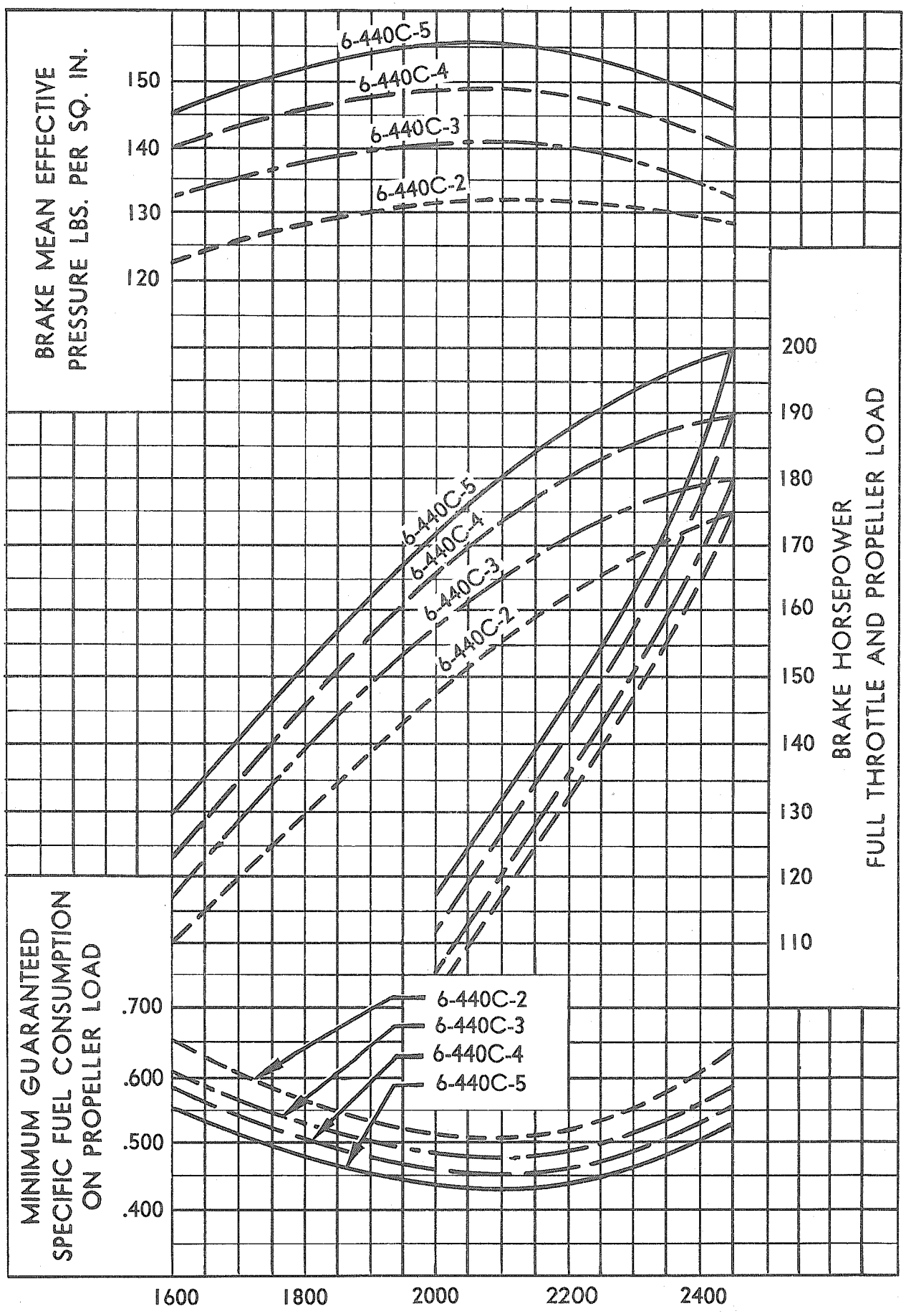
Test Procedure

Greater efficiency and accuracy can be obtained by following a definite system in taking the various readings required at each different engine speed. The sample log sheet, which is shown in Chapter VIII, is laid out so that the readings are approximately in the sequence in which they are to be taken. The test procedure will, therefore, be described with reference to the various columns on the test sheet. For purposes of identification, these columns have been numbered, although the column numbers need not appear on the sheets used for actual tests. The method of checking all the various data and entering them on the log sheet is the same at all engine speeds, except where otherwise stated. Therefore, only one sample reading of each type need be described as all subsequent readings are only repetitions of the first one.

As soon as the engine starts, the time of day should be entered in column 1 and the word "Start" should be entered in column 23. Columns 1 and 2 should be entered at the beginning of each period as soon as speed has been changed. All other columns should be entered after all readings have become stabilized at the particular engine speed for that period.

Time of Day

Column 1. Enter the time of day as previously described.



Performance Curves

Total Test Time

Column 2. Enter the total accumulated test time at the beginning of each period and at the end of the entire test.

Manifold Pressure

Column 3. Manifold pressure should be recorded at least once during every period. Limits are given only for 90% power.

Engine Speed

Column 4. Although the crankshaft speed can be read directly from the dial, errors in the instrument make it advisable to check the engine speed by actual count of the engine revolutions during a certain period of time. To do this, check the revolutions registered on the revolution counter and enter the reading obtained in column 6. Start the stop watch and the counter together, and time for about 1 minute. Stop both counter and stop watch together. Enter the revolutions indicated on the counter at the end of the test in column 5. Subtract from this the figure in column 6 and enter the difference in column 7. The interval of time shown by the stop watch should be entered in column 8. To obtain the correct engine speed in revolutions per minute, divide the number of revolutions made during the test by the number of seconds in column 8 and multiply by 60.

For instance, if 3581 revolutions were indicated on the revolution counter at the start of the test and 5801 revolutions at the end of the test, then the difference would be 2220 revolutions. Assuming the time taken for this check to be 74 seconds, then the engine speed would be:

$$\frac{2220 \times 60}{74} = 1800 \text{ RPM}$$

If the reading thus obtained differs from the speed specified in the test schedule by more than $\pm 2\%$, the throttle must be adjusted and the speed check repeated. The actual engine speed should then be entered in column 4.....470

Fuel Consumption

Column 10. Fuel consumption should be checked in order to test the carburetor. If fuel consumption is less than the minimum given in the table of operating limits, the carburetor is running so lean as to overheat the engine. If consumption is above the maximum limit, the carburetor is running so rich that the engine cannot develop maximum power. Since faulty mixture ratios are not always apparent when running the engine, a fuel consumption check is the only reliable test.

In order to check the fuel consumption, valve No. 4 on the fuel system diagram should be opened until the weighing tank on the scale is full. At this point, the main supply valve, No. 3, should be closed so that fuel is now supplied entirely from the weighing tank. The quantity in the weighing tank should be enough to permit timing the consumption over a time interval of at least 70 seconds. The quantity of fuel used for this test will naturally have to be increased as the fuel consumption increases with engine speed. The scale carries enough weight at all times to slightly over-balance the weight of the measuring tank when it is about one quarter full. To this must be added the weight of the amount of fuel used during the test. Assuming that 2 pounds of fuel will be used during the test, a 2 pound weight should be added to the weight already on the scale. The tank should then be filled up until the scale tips so that the tank is on the lower side. Then, as fuel is being drawn from this tank into the engine, the tank will become lighter until eventually the scale will tip back so that the tank is now on the higher side. At the moment the scale tips, the stop watch should be started. The timing of the engine speed and of the fuel consumption may be done together by pressing the button of the revolution counter at the same time as starting the stop watch.

As soon as the stop watch is started, remove the 2 pound weight which will again bring the measuring tank on the lower side. At the precise moment where the tank rises and the scale tips again, stop the stop watch and the revolution counter. Immediately after this, open valve No. 3 and close valve No. 4 as the engine might run out of fuel if

left running on the weighing tank. The weight of the fuel timed should be entered in column 9. After this, the consumption in pounds per hour can be obtained by dividing the weight in column 9 by the time in seconds in column 8 and multiplying by 3600. For instance, if it took 95 seconds to consume 2 pounds of fuel then fuel consumption would be:

$$\frac{2 \times 3600}{95} = 75.8 \text{ lbs/hr.}$$

Fuel Pressure

Column 11: The fuel pressure is read directly off the gage. If the fuel pressure is too low or too high, the fuel pressure adjustment valve in the main test stand fuel system should be adjusted. If the range of this valve is insufficient to bring the fuel pressure within the required limits, the fuel pressure relief valve incorporated in the engine driven fuel pump must be adjusted before continuing with a test run. If the pressure is too low, the engine will run too lean and may overheat. If the pressure is too high, the engine will run too rich.

Carburetor Air Temperature

Column 12. Carburetor air temperature can be read directly off the gage. It should be kept constant throughout the test, if possible, in order to avoid introducing another variable which may confuse the test data. Since the engine is designed to deliver rated horsepower at a carburetor temperature of 60° F., running at any other temperature will produce a change in the power. Within the carburetor air temperature limits recommended for running in, the variation is not great enough to affect readings. However, where carburetor air temperatures cannot be controlled closely enough, changes in carburetor air temperature will cause changes in engine speed. This must be taken into consideration when determining whether engine performance is satisfactory.

Oil-In Temperature

Column 13. It is important that the oil-in temperature be kept within the specified limits. In most climates, it will be necessary to cool the oil coming out of the engine. In this case, valve No. 8 on the oil diagram should be closed and valve No. 7 should be opened so that just enough water flows through the cooler to keep the oil at the proper temperature. In cold climates it may be necessary to actually heat the oil and in this case valve No. 7 should be closed and valve No. 8 should be opened just enough to keep the oil at the proper temperature. Valves 7 and 8 should never be opened together as the effect of steam and water would balance each other, resulting in wasteful operation.

Oil-Out Temperature

Column 14. The oil-out temperature is read directly off the gage. The normal increase of oil temperature within the engine varies with the weather and climate and no definite figures can be given. The normal temperature increase of the oil coming out of the engine over the oil entering the engine should be established for each particular test stand. A close check of the oil-out temperature may prove a valuable indication of malfunctioning of the engine. A sudden increase of the oil-out temperature should be immediately investigated and the engine should be shut down if no apparent reason can be found.

Oil Pressure

Column 15. Even though this pressure was adjusted during the warming up period, a normal increase of a few pounds per sq. in. with increase in engine speed is quite normal. An abnormal increase of the oil pressure may indicate improper functioning of the relief valve and the engine should be stopped for investigation. If the oil pressure is low, this may also indicate a sticking relief valve or a number of faulty conditions such as a faulty gage, lack of oil, leaks in the engine, etc. The cause of low oil pressure should always be remedied before continuing the test run.

Oil on Scales

Column 16. The total quantity of oil in the main supply tank can be read directly

off the scale on which the tank is mounted and should be recorded at the end of each period.

Oil Consumption

Column 17. By comparing each figure in column 16 with the last previous reading in that column, the total consumption in pounds at that particular speed can be obtained. By dividing this quantity by the number of minutes during which it was used and multiplying by 60, this oil consumption can be expressed in pounds per hour. The consumption should be calculated and recorded at every engine speed because inconsistancies between individual readings may indicate erratic engine performance which should be investigated.

Cylinder Head Temperatures

Columns 18, 19, 20 and 21. Thermocouples should be installed on the hottest cylinder heads. Since the location of these may vary with the location or the design of individual test stands, the thermocouple locations have been left blank on the test log sheet and should be filled in before the test run is started. Thermocouple readings are the best indication of over-heating, which may eventually lead to piston seizure. Therefore, the temperature of all thermocouples should be recorded at every engine speed. If any of the temperatures approach the permissible limits, the particular cylinder should be checked at frequent intervals. This is especially true towards the end of the test when the engine is delivering high power. Whenever a thermocouple indicates a cylinder temperature which has risen beyond the limit, the engine should be throttled back immediately. If the cause cannot readily be remedied, the engine must be switched off.

Remarks

Column 22. This column is used to note any extraordinary conditions encountered during the test. If the test has to be interrupted for any reason, this should be recorded in column 23. When the engine is finally stopped, the time should be entered in column 1, the total test time in column 2 and the word "Stop" in column 23.

Oil Flow

A maximum limit has ben placed on the oil flow because an excessive oil flow may result in high oil temperatures and high oil consumption in service. The oil flow should be checked during the rated power run in the following manner. With a stop watch at hand ready to time the test, close valve No. 1 on the test stand oil diagram. As oil continues to be drawn from the main oil tank, the pointer on the scale will immediately indicate that the tank is being emptied. Start the stop watch as the pointer passes a certain predetermined point on the scale, as soon as possible after valve No. 1 has been closed. Stop the run as soon as the pointer passes another pre-determined graduation on the scale. Valve No. 1 should be opened immediately afterwards so that the normal oil circulation will be restored. For greatest accuracy, a quantity of about 30 pounds should be measured. Assuming that the number of pounds of oil on the scale was 55 during the normal running of the engine, and assuming that the stop watch was started as the pointer passes 45, the stop watch can then be stopped as the pointer passes the 15 pound mark, after which the valve is again opened and the weight on the scale will return to the original figure. The quantity of oil drawn from the tank during the test was $45 - 15 = 30$ lbs. Assuming that this quantity was drawn from the tank in an elapsed time of 66 seconds, then the oil flow would be:

$$\frac{30 \times 60}{66} = 27.3 \text{ lbs/min.}$$

Magneto Check

After completion of the entire run, a magneto check should be made at 2100 RPM. While running at this speed, the magneto switch should be turned from "Both On" to "Right Mag" and "Left Mag". The drop in RPM on either magneto should be not more than the value stated in the Table of Operating Limits. The engine speed when running on both magnetos and when running on either one should be recorded in the proper location in the lower left hand corner of the test log sheet. When carrying

out this test, the engine should be run on each bank only once and only long enough for the engine speed to stabilize under that condition. Repeated indiscriminate switching from one set of spark plugs to the other may cause backfiring of the engine which may damage the engine and the test equipment.

Carburetor Tests

After the magneto check, the acceleration of the engine should be checked as follows. Throttle the engine all the way back to idling speed and then open the throttle at an even rate over a period of 8 to 10 seconds, to full throttle. Note whether the engine accelerates smoothly and without hesitation. Watch the exhaust for signs of smoke which would denote excessively rich mixture. Repeated violent movements of the throttle during this test are harmful to the engine.

At the end of the test, the idling speed and characteristics should be checked by pulling the throttle lever all the way back against the stop. A normal idling speed is from 400 to 500 RPM. If the idling speed is too high or too low, this can be adjusted by changing the position of the external throttle stop on the carburetor. If the engine runs rough or "rolls" at idling, it may indicate unsuitable mixture setting at idling speed. This can be adjusted by turning the idling mixture control on the carburetor. The engine should first be set to the best idling mixture and the mixture should then be made as rich as possible without affecting the idling characteristics.

Run-Out on Unleaded Fuel

If the engine is to be prepared for long term storage, it will have to be run for an additional period on unleaded gasoline and using special corrosion preventive oil. This procedure is described in Chapter VII.

Stopping the Engine

After all test runs have been completed, the engine should be shut off in the following manner. Throttle the engine back to about 800 RPM and let it idle until all cylinder head temperatures are below 250°F. Move the mixture control lever all the way up against the stop on the lean side of the quadrant. This will engage the fuel cut-off at the carburetor. Start a stop watch at the moment the mixture lever is in the cut-off position and stop the watch as soon as the engine ceases firing. The time for the engine to stop in this manner should not exceed 7 seconds. Enter the time to stop on the log sheet. Be sure to switch off the magneto switch as soon as the propeller has stopped rotating.

Oil Leak Check

Examine the engine on the stand for signs of oil leaks immediately after it has been switched off. If any traces of oil are found, the origin of which cannot definitely be traced, wipe off the particular part of the engine, then start it again and run for about 10 more minutes. After this, switch off and check whether any more oil has accumulated on the previously cleaned surfaces. If a leak is found in any location where it can be corrected on the test stand, this should be done and the engine should then be run again to make sure that the trouble has been corrected. If a leak develops in a location such as at the main crankcase parting surface or at the cylinder pads, the engine must be removed from the stand to correct the leak.

REMOVAL FROM STAND

As soon as it is decided that the engine can be removed from the stand, disconnect the electrical system by disengaging the master switch at the battery.

The breather outlet pipe should be disconnected as soon as the engine is stopped, even if it is only to be stopped for a comparatively short period. The reason for this is that the breather outlet points straight up and a portion of the breather outlet connection will, therefore, inevitably be in such a position that any condensate of crankcase vapors which has accumulated in the breather outlet pipe may run back into the engine where it may cause corrosion.

The propeller should be removed as soon as possible after the test run is completed.

When doing this, care should be taken to avoid turning the propeller while the engine is still hot. After the propeller and all attaching parts have been removed, the propeller shaft should be protected with a protective sleeve and cap.

Disconnect the thermocouples, remove all accessories which are not to be shipped with the engine and install the proper replacement covers. Remove the oil lines, fuel lines and various gage connections and close off the openings with the proper plates or plugs. Remove the air scoop. Remove the carburetor intake pipe and connections and install a cover plate over the carburetor opening. Take off the exhaust pipes and install suitable cover plates over the exhaust port openings. After all parts and accessories which can be removed on the test stand have been taken off, the magneto ground wires should be disconnected.

Move the chain hoist into position over the engine, insert the hook of the hoist in the lifting eye and take up the slack in the chain. Take out the engine mounting bolts and inspect the entire installation to see that all connections have been disconnected. Then lift the engine high enough so that it can be moved away from the test stand, being careful to guide the engine so that it cannot strike any part of the test stand. Lower the engine onto Assembly Stand, AT 182 and bolt engine to stand.

INSPECTION AFTER TEST

After the engine on the assembly stand has been moved out of the test cell, it should be tilted so that the propeller end of the camshaft points up at an angle of about 45°. Oil should then be drained from the camshaft housing by removing the two drain plugs from the scavenge pump. Take out and clean the main oil filter and clean out the quantity of oil which remains in the oil filter housing in the rear section with a clean rag. Replace the oil filter.

Invert the engine on the stand and reinstall, tighten and safety the oil drain plugs.

Take off the camshaft housing front cover, losen the scavenge pump and remove the camshaft housing cover. Remove the pins which safety the rocker arm support nuts and check the tightening torque of these nuts using Torque Wrench, AT-359. Then replace the safety pins. Check the clearance of all valves and adjust as necessary. Check all valve adjusting screw locknuts for tightness. Clean the parting surface of the camshaft housings with alcohol, cover the surface with gasket compound and replace the covers. Tighten the center pair of flange nuts first and then tighten the other nuts working from the center towards both ends of the camshaft housing covers. Tighten the scavenge pumps and reinstall the camshaft housing front covers.

Check the cylinder hold-down nuts for tightness using Wrench, AT-251 and Torque Wrench, AT-359. Check the cylinder hold-down locknuts for correct installation.

Check the hose clamps on the scavenge oil rear drain pipe for tightness. Safety wire all pipe plugs and replacement covers which were installed after the various connections were removed from the engine and check the safety wiring in all other locations on the engine.

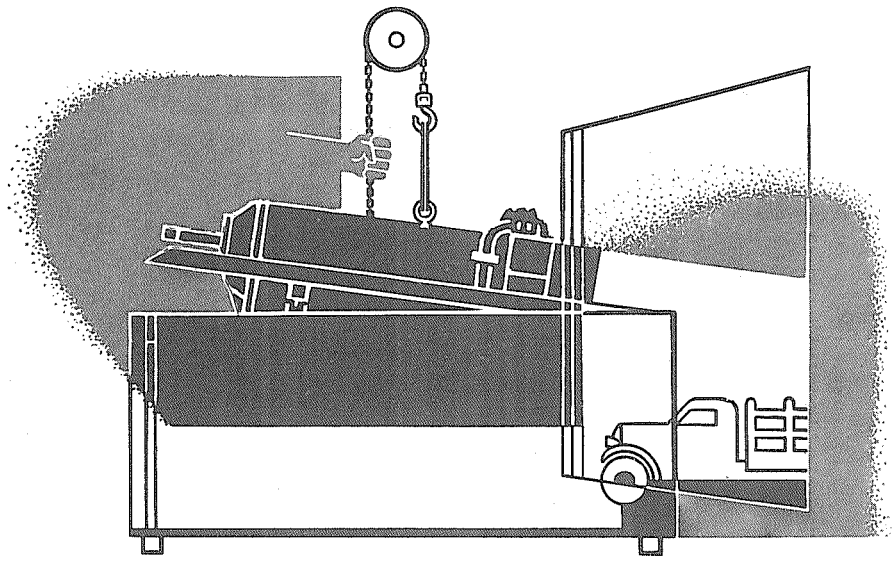
Turn the engine on the assembly stand so that it is in the normal position. Check all crankcase flange nuts for tightness and check the nuts holding the front and rear crankcase assemblies to the main crankcase.

Using Thrust Nut Wrench, AT-137, loosen the propeller thrust nut about ½ turn and then tighten it fully. This procedure must be followed, as it is impossible to check for proper tightness without first loosening the nut.

Check all cylinder baffles for tightness, clearance and correct installation. A general inspection of the entire engine should then be made to check for possible signs of damage caused during the test run or during the installation and removal of the engine. During this inspection, particular attention should be paid to the ignition harness, the intake system and the baffles.

After the inspection has been completed, the entire engine should be cleaned with a solvent spray and a clean soft rag and should then be dried with compressed air.

CHAPTER VII



PREPARATION FOR STORAGE AND PACKING

This chapter describes in detail the method of preparing the 6-440C engine for long term storage in accordance with Specification AN-F-E-568a. The following are the basic materials used for this process.

Corrosion preventive oil to Specification AMS-3070.

Corrosion preventive compound to Specification AMS-3072.

Transparent moisture resistent engine envelope made of plastic film to Specification AMS-3610 (Pliofilm).

Silica-Gel dehydrator agent to Specification AMS-3420.

The detail parts required for the preparation for storage of the 6-440C engine such as the correct type of dehydrator plugs, special cover plates, etc. are described in the Parts Catalog.

In actual practice, the preparation for storage is made a part of the test run and subsequent operations. However, corrosion proofing has been described in a separate chapter, since there may be instances where a test run is made without the need for subsequent preparation for storage.

RUN-OUT ON TEST STAND

Where it is necessary to prepare the engine for long term storage, the engine should be run on the stand for an additional period as follows: After the test run has been satisfactorily completed and the engine has been stopped, close valves 3 and 4 on the oil diagram, thus closing off the main oil system. Drain the oil from the camshaft housing by removing the drain plugs at the scavenge pump. Replace, tighten and safety the plugs. Fill the special corrosion proofing oil tank in the system with at least three gallons of the corrosion proofing compound. New oil must be used for each engine. Then open valves 5 and 6 on the test stand oil diagram to connect the tank with the engine. On the test stand fuel system diagram, close valve 2 and open valve 1. The fuel used during this run must be clear, unleaded gasoline since one of the purposes of the run is to remove any trace of lead deposits from inside the engine which might otherwise cause corrosion during the storage period.

Start the engine and run it for 15 minutes at a speed not exceeding 1500 RPM. To run it at a higher engine speed would be dangerous as the fuel being used is of a lower octane rating than that required, and detonation may therefore result when running at higher power output. The oil inlet temperature during this test must be above 145°F. During this run, the fuel weighing system must not be operated, in order to prevent diluting the fuel in the system with a fuel of a lower octane rating.

At the end of the run, the main fuel valve should be closed with the engine still running at 1500 RPM. As soon as the engine stops, the magneto switch must be turned to the "Off" position.

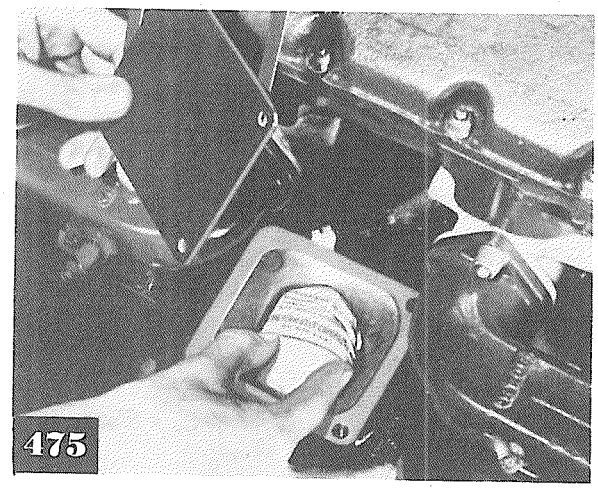
Accessory Drives

Remove the engine from the test stand and install on the engine assembly stand as described in Chapter VI. Drain the camshaft housings by removing the drain plugs at the scavenge pumps. Remove the main oil filter, clean off all the oil with a solvent spray, then dip the filter element in corrosion proofing compound and reinstall on the engine. Remove the replacement covers from the mounting pads for the generator, starter, vacuum pump and fuel pump. Wipe all traces of engine oil off the exposed ends of the accessory drives and brush them with corrosion proofing compound. Replace the replacement covers, using new gaskets if necessary, making sure that they form an air-tight seal.

Invert the engine on the assembly stand and take out the spark plugs. Reinstall, tighten and safety the drain plugs in the scavenge pump. Take off the carburetor.

Carburetor

Empty the carburetor of all residual gasoline and pour corrosion proofing oil, in accordance with Specification AMS-3070, into the fuel inlet of the carburetor until no more oil will enter. Then close off the fuel inlet opening and turn the carburetor over a few times to make sure that the oil will reach all inside surfaces of the carburetor. Excess oil should then be drained and the

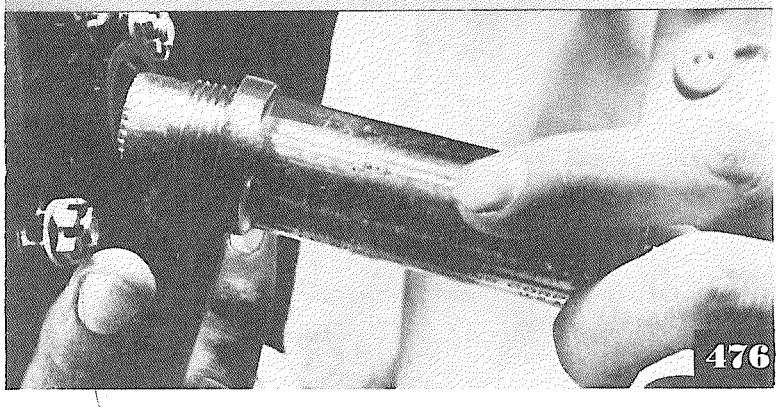


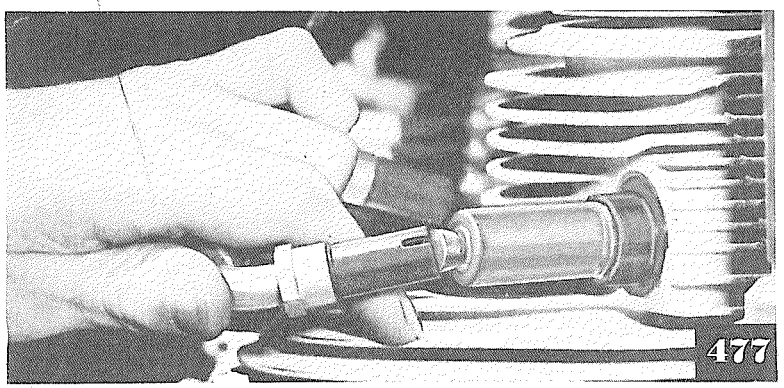
fuel inlet should be closed off with a pipe plug which is safetied by wiring it to the pipe plug closing off the fuel pressure takeoff. The throat of the carburetor should be sprayed with corrosion proofing compound with the throttle in the open position. After this, the throttle should be wired in the full open position. The mixture should be wired in the full rich position. After corrosion proofing, the carburetor should again be installed on the engine.

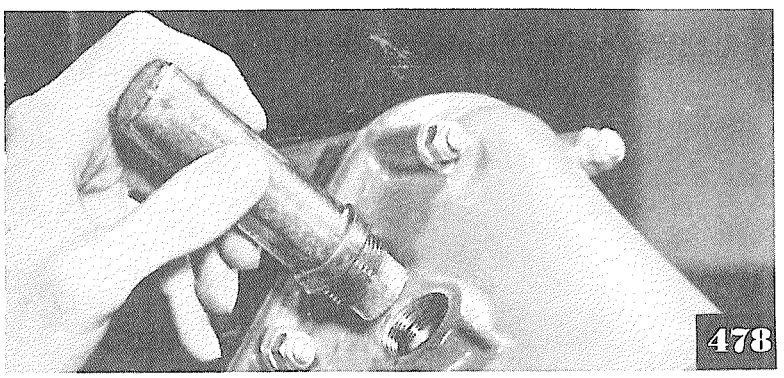
Tie a one eighth pound bag of Silica-Gel into position in the carburetor throat. . **475** Install the carburetor intake gasket and cover plate and secure with the necessary nuts.

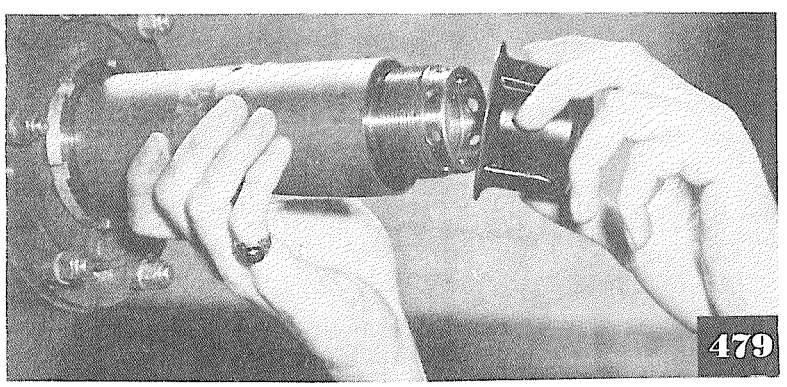
Cylinders

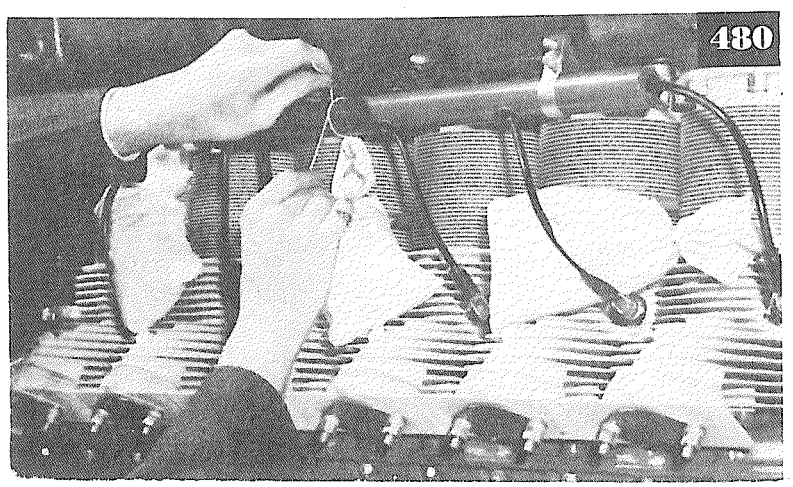
Turn the crankshaft until the exhaust valve on any one cylinder opens and then spray a sufficient quantity of corrosion proofing compound into the particular exhaust port to cover the stem and the seat of the exhaust valve. Turn the crankshaft through another ½ revolution so that the intake valve opens. Spray the intake valve with corrosion proofing compound by inserting the spray nozzle through the intake side spark plug. Turn the crankshaft further until the piston is at bottom dead center and then spray a sufficient quantity of corrosion proofing compound through the exhaust spark plug hole into the combustion chamber to thoroughly coat the cylinder walls. Repeat this procedure for all other cylinders. Cylinder walls must be sprayed within two hours after the engine is stopped.











Remove the camshaft housing front cover and install a special cover which has a hole with a $\frac{3}{4}$" pipe thread in the center. Install a plastic dehydrator plug in this hole. 476

When installing any dehydrator plugs, do not remove the protective cap until immediately before installation.

Install dehydrator plugs in all spark plug holes. On unshielded ignition systems, attach the wire terminals directly to the ends of the dehydrator plugs. On shielded ignition systems, install cable protectors over the ends of the spark plug elbows; then attach the protectors to the dehydrator in the cylinders. 477

Install the exhaust port gaskets, install suitable cover plates and tighten the nuts so as to obtain an air-tight joint.

Install a $\frac{3}{4}$" dehydrator plug in the vent hole in the right side of the front crankcase section. 478

Install a similar dehydrator plug in the vent hole in the rear crankcase immediately to the left of the starter pad. Spray the propeller shaft with corrosion proofing compound. Install a protective sleeve over the splines and install a protective cap over the propeller nut threads. 479

All other openings on the engine should then be closed off air-tight with suitable covers or pipe plugs. Tie three one-pound bags of Silica-Gel to each side of the cylinder bank so that they are evenly distributed. 480

Installing Pliofilm Bag

Attach a hoist to the engine, loosen the mounting bolts and lift the engine off the assembly stand. The pliofilm bag should be stretched out underneath the engine and should then be carefully raised by two men, making sure that it is not torn by coming in contact with sharp corners of the engine. 481

The envelope should be temporarily held in place by taping the upper edge to the engine with adhesive tape.

Gaskets which serve to make an air-tight joint at the mounting bolts are attached to the bag. Insert the mounting bolts through

the hole in the proper gasket, with a washer on the outside of the upper and lower gasket, to hold the bag in position. Lower the engine into the box, being careful not to tear the bag by contact with the box or the mounting rails. Install castellated nuts on the four bolts holding the mounting brackets to the supporting rails and safety with cotter pins.

Remove the lifting eye from the top of the crankcase. Fold the bag over the top of the crankcase so that the lifting eye studs protrude through the proper gaskets. Reinstall the lifting eye and tighten the two self-locking nuts.

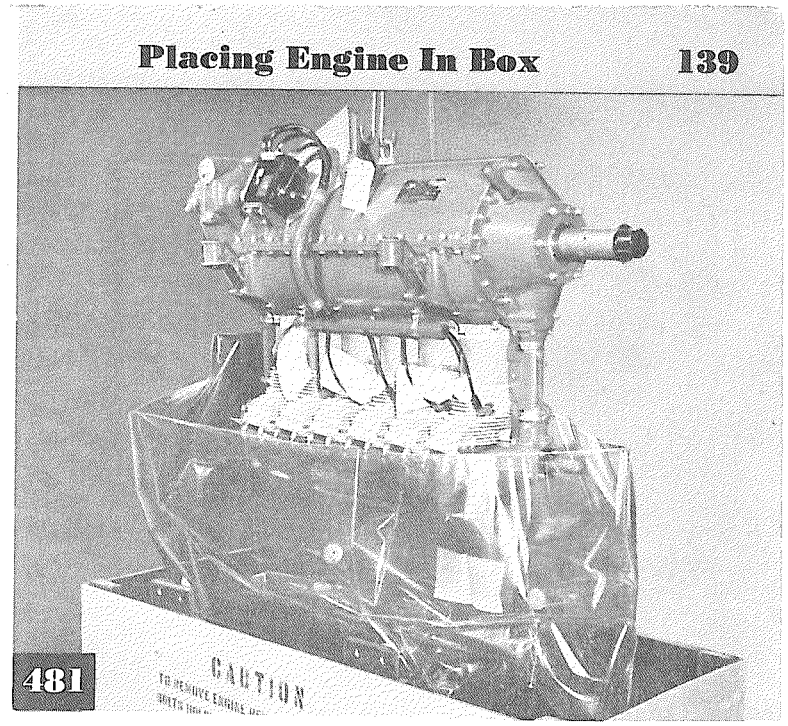
Attach the humidity indicator to a plywood board of suitable size and attach this board to the studs holding the starter replacement cover. 482

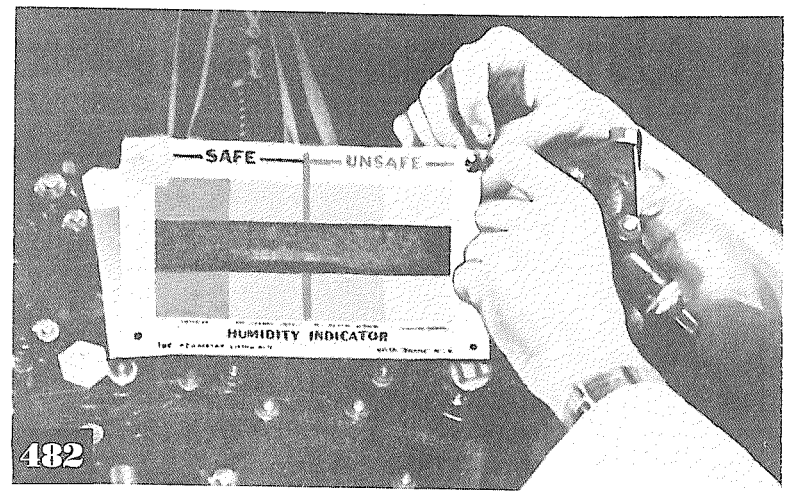
Do not remove the indicator from its envelope until it is ready for attachment to the engine. The humidity indicator as well as the various dehydrator plugs and the Silica-Gel in the bags should have a moisture content of not more than 10% as indicated by the color chart on the indicator after the bag has been sealed.

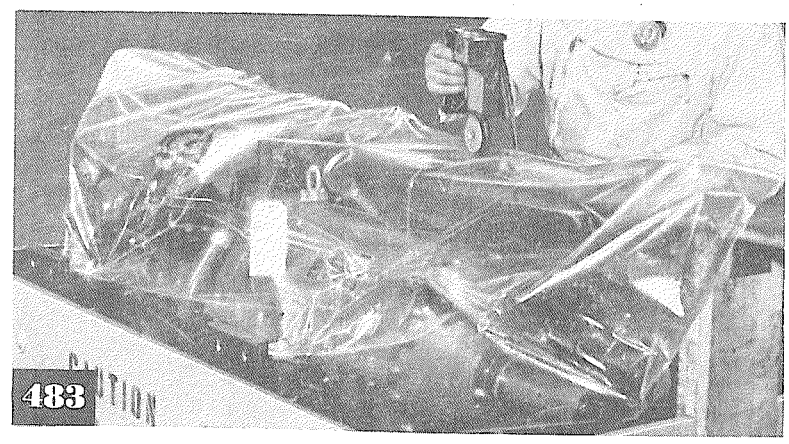
The edges of the bag are sealed together with a special heating iron. 483

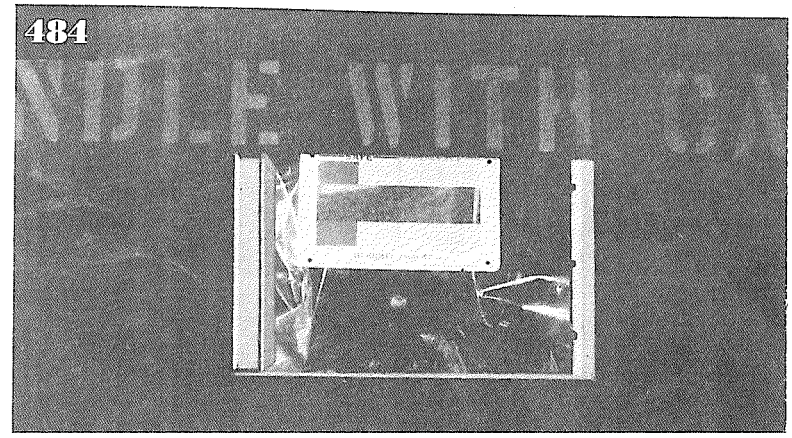
Loose folds of the envelope should be drawn tight and should be secured with colored adhesive tape to prevent tearing. Care must be taken to have not more than a single thickness of pliofilm covering the humidity indicator. Detached parts such as the camshaft housing front cover, spark plugs, gaskets, etc. should be securely packed in a box which is then placed in a separate pliofilm bag with a sufficient amount of Silica-Gel to comply with the specifications. Any accessories not shipped on the engine should be packed in the same way. The engine box cover should then be carefully lowered over the box being careful not to strike any part of the engine or envelope. The inspection door in the box cover must be opposite the humidity indicator. 484

Install the eight cap screws in the steel reenforcing straps around the engine box. Safety the cap screws with wire and also safety wire the inspection door.









CHAPTER VIII

SUPPLEMENTARY INFORMATION

APPROVED ACCESSORIES

The accessories listed below have been tested and approved by Ranger Aircraft Engines. The factory should be consulted before attempting to install any other type of equipment on the engine.

TYPE	MANUFACTURER	MODEL
Carburetor	Stromberg Aircraft Carburetor Div. Bendix Products Division South Bend, Indiana	NA-R4B
Carburetor	Marvel-Schebler Carburetor Div. Borg-Warner Corporation Flint, Michigan	MA-4-5
Magneto, Right	Scintilla Magneto Division Bendix Aviation Corporation Sidney, New York	SB6RN-8
Magneto, Left	Scintilla Magneto Division Bendix Aviation Corporation Sidney, New York	SB6RN-10
Magneto, Right	Edison-Splitdorf Corporation West Orange, New Jersey	SB6RD-1
Magneto, Left	Edison-Splitdorf Corporation West Orange, New Jersey	SB6RD-2
Spark Plugs	A. C. Spark Plug Division General Mortors Corporation Flint, Michigan	C-25
Spark Plugs	BG Corporation 136 West 52nd Street New York, New York	417
Starter, Hand	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type 393 Model 4

APPROVED ACCESSORIES—continued

TYPE	MANUFACTURER	MODEL
Starter, Electric	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type 396 (Y150)
Starter, Electric	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type 397 (E80)
Generator	Ranger Aircraft Engines Division Fairchild Eng. & Airplane Corp. Farmingdale, New York	NA-1 *
Voltage Regulator	Delco Remy Division General Motors Corporation Anderson, Indiana	No. 1118254 *
Generator	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type 309 *
Voltage Regulator	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type 320 *
Fuel Pump	Romec Pump Company 347 East Bridge Street Elyria, Ohio	RB-4360
Fuel Pump	Pump Engineering Service Corp. 12910 Taft Avenue Cleveland, Ohio	227-DA
Hydraulic Pump	Pump Engineering Service Corp. 12910 Taft Avenue Cleveland, Ohio	IP-203-RA
Vacuum Pump	Pump Engineering Service Corp. 12910 Taft Avenue Cleveland, Ohio	207-D
Vacuum Pump	Eclipse Aviation Division Bendix Corporation Bendix, New Jersey	Type B-2A Model 548-3A

* Must be used together.

OVERHAUL TOOL LIST

The following is a list of the special tools used in the overhaul of the 6-440C engines. Since the method of using each tool has been fully described in the appropriate section, tools have been listed below in numerical order. The prefix letters "AT" are a significant part of the tool number and must be included for identification when ordering tools.

TOOL NO.	TOOL NAME	TOOL NO.	TOOL NAME
AT-11	Gage—Valve clearance	AT-166	Indicator—Timing
AT-14	Compressor—Valve Spring	AT-160	Wrench—Valve Adjusting
AT-39	Wrench—Spark Plug	AT-182	Stand—Engine Assembly
AT-46	Wrench—Intake pipe packing nut spanner	AT-183	Sling—Engine lifting
		AT-184	Rack—Parts
AT-57	Holder—Exhaust valve lapping	AT-185	Support—Crankshaft and run-out indicator
AT-58	Holder—Intake valve lapping		
AT-59	Tool—Intake valve guide boring	AT-186	Remover—Piston pin circlip
AT-60	Tool—Exhaust valve guide boring	AT-187	Drift—Fuel pump drive oil retainer
AT-61	Holder—Intake valve guide		
AT-62	Holder—Exhaust valve guide	AT-188	Puller—Vacuum pump and tachometer drive housing assembly
AT-90	Bar-Cylinder aligning		
AT-110	Drift—Piston pin bushing	AT-190	Stand—Crankshaft assembly
AT-120	Eye—Crankshaft lifting	AT-191	Gage—Piston ring cap 4-1/8 dia.
AT-122	Expander—Piston ring	AT-192	Wrench—Connecting rod
AT-133	Clamp—Piston ring	AT-193	Screw Driver—Connecting rod
AT-137	Wrench—Thrust nut	AT-194	Mandrel—Connecting rod bushing peening
AT-139	Driver—Thrust bearing		
AT-140	Puller—Thrust plate and front crankcase	AT-195	Jig—Connecting rod alignment
		AT-196	Drift—Vacuum pump drive oil retainer
AT-142	Drift—Piston pin		
AT-143	Cutter—Intake valve seat	AT-197	Bar—Crankcase separating
AT-144	Cutter—Exhaust valve seat refacing	AT-198	Puller—Starter driving jaw
		AT-199	Drift—Starter driving jaw
AT-147	Puller—Magneto drive coupling	AT-200	Tool—Starter driving jaw rivet back-up
AT-148	Wrench—Magneto coupling		
AT-153	Wrench—Spark Plug	AT-201	Tool—1/8 diameter rivet heading
AT-158	Wrench—Box and open end, 1/2 inch	AT-202	Remover—Magneto drive oil retainer

OVERHAUL TOOL LIST—Continued

TOOL NO.	TOOL NAME	TOOL NO.	TOOL NAME
AT-203	Drift—Magneto drive oil retainer	AT-234	Driver—Necked cylinder head stud
AT-204	Puller—Accessory drive shaft front gear	AT-235	Driver—Screw bushing
AT-205	Drift—11/16 cup plug	AT-236	Drift—1-17/32 cup plug
AT-206	Drift—17/32 cup plug	AT-237	Fixture—Valve seat refacing
AT-207	Puller—Pressure oil pump gear	AT-238	Handle—Ratchet
AT-208	Guide—Tachometer drive adapter	AT-239	Wrench—Vertical drive shaft housing packing nut spanner
AT-209	Separator—Rocker arm support and camshaft bearing assembly	AT-291	Gage—Valve spring compression
		AT-292	Gage—Piston pin bushing
AT-210	Drift—Camshaft front cup plug	AT-293	Roller—Crankshaft inspection
AT-211	Drift—Camshaft rear cup plug	AT-307	Cutter with Holder—Intake valve seat recess counterbore, .005 inch oversize.
AT-212	Fixture—Upper vertical drive gear alignment		
AT-214	Drift—Vertical drive shaft cup plug	AT-308	Cutter—Intake valve seat recess counterbore, .010 inch oversize
AT-215	Block—Cylinder assembly	AT-309	Cutter—Intake valve seat recess counterbore, .015 inch oversize
AT-216	Masking equipment—4-1/8 cyl.		
AT-217	Gage—Intake valve guide replacement maximum plug	AT-310	Cutter—Intake valve seat recess counterbore, .020 inch oversize
AT-218	Gage—Exhaust valve guide replacement maximum plug	AT-311	Cutter with holder — Exhaust valve seat recess counterbore, .005 inch oversize
AT-219	Gage—Exhaust valve guide standard plug	AT312	Cutter—Exhaust valve seat recess counterbore, .010 inch oversize
AT-220	Gage—Intake valve guide standard plug	AT-313	Cutter—Exhaust valve seat recess counterbore, .015 inch oversize
AT-221	Fixture—General cylinder repair holding	AT-314	Cutter—Exhaust valve seat recess counterbore, .020 inch oversize
AT-222	Tool—Intake valve seat boring	AT-320	Reamer—Intake valve guide cylinder hole expansion, .005 inch oversize
AT-223	Tool—Exhaust valve seat boring		
AT-224	Holder—Valve seat		
AT-226	Driver—Spark plug insert	AT-321	Reamer—Intake valve guide cylinder hole expansion, .010 inch oversize
AT-227	Jig—Spark plug insert lock pin drill		
AT-228	Remover—Fuel pump drive oil retainer	AT-322	Reamer—Intake valve guide cylinder hole expansion, .015 inch oversize
AT-233	Driver—Main bearing stud		

OVERHAUL TOOL LIST - Continued

TOOL NO.	TOOL NAME	TOOL NO.	TOOL NAME
AT-323	Reamer—Intake valve guide cylinder hole expansion, .020 inch oversize	AT-337	Gage—Exhaust valve guide cylinder hole limit plug, .020 inch oversize
AT-324	Reamer—Exhaust valve guide cylinder hole expansion, .005 inch oversize	AT-338	Reamer—Intake valve guide expansion
AT-325	Reamer—Exhaust valve guide cylinder hole expansion, .010 inch oversize	AT-339	Reamer—Exhaust valve guide expansion
AT-326	Reamer—Exhaust valve guide cylinder hole expansion, .015 inch oversize	AT-359	Wrench—Torque
AT-327	Reamer—Exhaust valve guide cylinder hole expansion, .020 inch oversize	AT-370	Arbor—Connecting rod
AT-328	Pilot—Valve seat and valve guide rework	AT-373	Rack—Valve
AT-330	Gage—Intake valve guide cylinder hole limit plug, .005 inch oversize	AT-374	Counterbore—Cutter with 5/8 pilot
AT-331	Gage—Intake valve guide cylinder hole limit plug, .010 inch oversize	AT-378	Tap—Spark plug insert hole, .005 inch oversize
AT-332	Gage—Intake valve guide cylinder hole limit plug, .015 inch oversize	AT-379	Puller—Cup plug
AT-333	Gage—Intake valve guide cylinder hole limit plug, .020 inch oversize	AT-382	Gage—Lower vertical drive gear alignment
AT-334	Gage—Exhaust valve guide cylinder hole limit plug, .005 inch oversize	AT-385	Fixture—Connecting rod alignment
AT-335	Gage—Exhaust valve guide cylinder hole limit plug, .010 inch oversize	AT-386	Tap—Spark plug insert hole .010 inch
AT-336	Gage—Exhaust valve guide cylinder hole limit plug, .015 inch oversize	AT-387	Tap—Spark plug insert hole .015 inch
		AT-392	Puller—Tachometer drive idler gear shaft
		AT-401	Bar—Camshaft housing bearing boring
		AT-402	Boredrill—Camshaft Housing Bearing
		AT-403	Jig—(Drilling and installing camshaft bearing bushings)
		AT-404	Puller—Crankshaft large plug
		AT-405	Gage—Crankshaft run-out
		AT-423	Jig—Front and main crankcase bearing rework

OVERHAUL TOOL LIST—Continued

TOOL NO.	TOOL NAME	TOOL NO.	TOOL NAME
AT-424	Jig—Main and rear crankcase bearing rework	AT-447	Punch
		AT-447	Punch
AT-425	Holder—Boredrill	AT-448	Sleeve — Used with jig 403
AT-426	Boredrill— .937 inch	AT-449	Drift
		AT-449	Drift
AT-427	Boredrill—1.000 inch	AT-451	Drift—Valve rocker bushing
AT-428	Boredrill—1.219 inch	AT-452	Gage—Valve rocker replacement maximum plug
AT-429	Boredrill—1.500 inch		
AT-430	Boredrill— .922 inch	AT-453	Anvil—Valve rocker roller riveting
AT-431	Boredrill—1.125 inch	AT-454	Punch—Valve rocker roller riveting
AT-432	Cutter—Facing		
AT-433	Cutter—Chamfering	AT-464	Cutter—Exhaust valve seat relieving
AT-444	Holder—Facing cutter	AT-592	Propeller—Engine test
AT-445	Boredrill—1.000 inch	AT-594	Kit—Stud replacement

SHOP MATERIALS

The following list has been prepared to assist overhaul shops in selecting the material most suitable for the overhaul of Ranger engines. The listing of any product does not mean that it must be used exclusively. Other products may give equally satisfactory results. However, only those materials which in the experience of Ranger Aircraft Engines have proved satisfactory, have been listed.

OILS AND GREASES

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Lubricating; engine.	Grade 1120	Any oil to Spec. AN-VV-O-446
Lubricating; anti-friction bearings.	Gargoyle Grease BRB #2	Socony-Vacuum Oil Co. Inc. 230 Park Ave., New York, N. Y.
Lubricating; studding, tapping, reaming, drilling steel.	Sultex A-1	The Texas Company 135 East 42nd Street New York, New York
Lubricating; studding, tapping. reaming, drilling of steel, aluminum and magnesium.	Sunicut 9810	The Sun Oil Company 420 Lexington Avenue New York, New York
Lubricating; studding, tapping, reaming of aluminum and magnesium.	Almag Cutting Oil	The Texas Company 135 East 42nd Street New York, New York
Lubricating; tapping and studding aluminum and magnesium.	3 X Castor Oil	The Baker Castor Oil Company Jersey City, New Jersey
Lubricating; tapping and studding aluminum, magnesium and steel.	Grade 120 Mobiloil	Socony-Vacuum Oil Co. Inc. 230 Park Ave., New York, N. Y.
Coolant; honing.	International Compound #155 (See Formula)	International Compound Co. Philadelphia, Pennsylvania
Coolant; grinding.	International Compound #137 (See Formula)	International Compound Co. Philadelphia, Pennsylvania

OILS AND GREASES—Continued

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Coolant; grinding exhaust valve seats and crankshafts.	Mineral Seal Oil (See Formula)	Colonial Beacon Oil Company 30 Rockefeller Plaza New York, New York
Coolant; grinding aluminum.	Soluble D Oil	The Texas Company 135 East 42nd Street New York, New York
Coolant; grinding exhaust valve seats.	Cut-Max. Base #2 (See Formula)	E. F. Houghton Company Philadelphia, Pennsylvania
Coolant; valve facing machine, also grinding steel and aluminum.	Economy Lubricant E-1	The White & Bagley Company Worcester, Massachusetts
Corrosion Preventive (exterior)	Whiz Compound 3568 E	R. M. Hollingshead Corporation Camden, New Jersey
Rust Preventive (steel parts)	Quaker Ferrocote #349	The Quaker Chemical Company Conshohocken, Pennsylvania
Rust Preventive (steel parts)	Rust Ban #392	Colonial Beacon Oil Company 30 Rockefeller Plaza New York, New York
Quenching Oil (Hot oil bath)	Houghton's #2	E. F. Houghton Company Philadelphia, Pennsylvania
Thread Lubricant; Steel on Steel.	Dixon's #3 Graphite	Joseph Dixon Crucible Company 233 Broadway, New York, N. Y.
Lubricant; Steel threads into aluminum or magnesium parts.	Alcoa Thread Lubricant	Aluminum Company of America 230 Park Ave., New York, N. Y.
Lubricant; Spark Plug Threads.	Mica Lubricant	BG Spark Plug Company 136 West 52nd Street New York, New York
Seal for Cylinder Head joints.	"Heldtite" Compound	Held Glue and Compound Co. Brentford, Middlesex, England

CLEANING EQUIPMENT

Cleaning Booths.	To Specification	The De Vilbiss Company Toledo, Ohio

CLEANING EQUIPMENT — Continued

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Cleaning Fluid.	Varsol	Colonial Beacon Oil Company 30 Rockefeller Plaza New York, New York
Protective cream; hands.	Pro-tek #7	Du Pont De Nemours & Co. Inc. Wilmington, Delaware
Protective Gloves.	Long-sleeved	The Surety Rubber Company Carrollton, Ohio
Protective Masks; face, eyes, nose.	Pro-tek Masks	Martindale Electric Company Cleveland, Ohio
Protective Masks; Spray Booth.	Model 1110	Dockson & Company Detroit, Michigan
Degreasing Chemical.	Cecoline	Du Pont De Nemours & Co. Inc. Wilmington, Delaware
Cleaning Chemical.	Caustic Soda (See Formula)	Seldner and Endquist, Inc. 86 Hausman Street Brooklyn, New York
Stripping and softening chemical.	Carbrax	Turco Products Company Los Angeles, California

ABRASIVES

Honing stones; polishing-finishing.	Grits 240 to 500	Sunnen Products Company St. Louis, Missouri
Grinding Stones	N54B H35A	Sterling Grinding Wheels Co. Tiffin, Ohio
Grinding Wheels	All Grits	The Norton Company Worcester, Massachusetts
Buffing Wheels	Cotton and Felt	L. Best and Company 28 West Broadway New York, New York
Wire Wheels	"Fine" to "Coarse"	Osborn Manufacturing Company New York, New York
Polishing Rouge; for soft metal	Tripoli	L. Best and Company 28 West Broadway New York, New York

ABRASIVES — Continued

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Polishing Rouge; finish	White Diamond	L. Best and Company 28 West Broadway New York, New York
Emery Paste	All Grades	Munning and Munning Newark, New Jersey
Emery cloth; emery discs, rope emery	Metalite Cloth Grits 80 to 400 "Lightning" "Three M-ite"	Behr-Manning Company Troy, New York
Crocus Cloth for polishing	Grit 500	Behr-Manning Company Troy, New York
Lapping Compound for grinding valves and lapping steel threads on steel shafts.	3-M Oil Mix 80E-220B-500-(2A)	Minnesota Mining and Mfg. Co. St. Paul, Minnesota
Lapping Compound; valves and soft metal surfaces.	Clover Compound Grits A to E (fine to coarse)	Clover Manufacturing Company Norwalk, Connecticut
Cleaning Steel Parts	Steel Wool	The American Steel Wool Co. 42-24 Orchard Street Long Island City, New York
Rubber abrasive; lathe wheels, hand pieces, sticks for use in restricted areas.	Bright-Boy	Weldon Roberts Rubber Co. Newark, New Jersey
Grit for Sandblasting cylinders	Pfaffblast #30	George Pfaff Company 11-02 Jackson Avenue Long Island City, New York
Grit for Sandblasting cylinders	Metcolite F. Grit	Metallizing Engineering Co. 21-07 41st Avenue Long Island City, New York
Grit for cleaning, stripping in sandblast.	Exner #1	Exner Sand and Gravel Corp. 880 Zerega Ave., Bronx, N. Y.
Grit for cleaning, stripping in sandblast.	Pangborn IH	The Pangborn Company Hagerstown, Maryland
Sandblasting Equipment	To Specification	The Pangborn Company Hagerstown, Maryland

PAINTING EQUIPMENT AND MATERIALS

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Paint Spray Booths	To Specification	The De Vilbiss Company Toledo, Ohio
Paint Spray System Regulators	Type HLC	The De Vilbiss Company Toledo, Ohio
Paint Spray Guns	Type MBD	The De Vilbiss Company Toledo, Ohio
Paint Spray Guns	Thor Model	Binks Manufacturing Company Chicago, Illinois
Protective treatment for magnesium	Sodium Dichromate solution (See Formula)	Seldner and Endquist, Inc. 86 Hausman Street Brooklyn, New York
Primer	Zinc Chromate P-27-B	Sherwin-Williams 292 Madison Avenue New York, New York
Engine Paint	Gray Phthalate enamel E-5-E; Spec. amen. 2	Egyptian Lacquer Company 1270—6th Avenue New York, New York
Reducer	Aerotol 32062	Sherwin-Williams 292 Madison Avenue New York, New York

CORROSION PROOFING EQUIPMENT AND MATERIALS

Slushing Pressure System	Type Q-3	The De Vilbiss Company Toledo, Ohio
Slushing Spray Gun	Type CL	The De Vilbiss Company Toledo, Ohio
Slushing System Regulator	Type FM	The De Vilbiss Company Toledo, Ohio
Dehydrator Material (Silica-Gel)	Protek-Sorb 695-420 X-1036	The Davison Chemical Company Baltimore, Maryland
Dehydrator Plugs (Camshaft Housings)	Protek Plugs #9800	Chandler-Evans Corporation Meriden, Connecticut

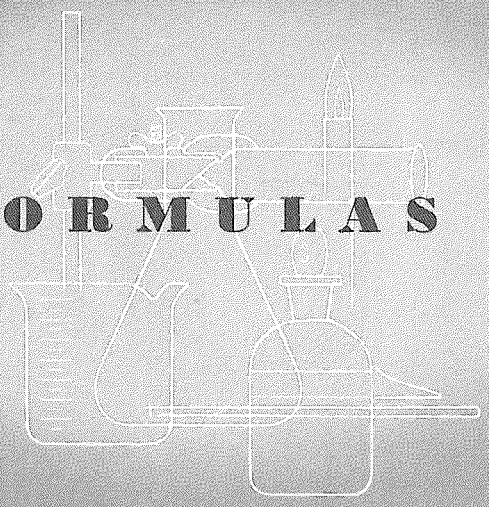
CORROSION PROOFING MATERIALS AND EQUIPMENT—Continued

PURPOSE	TRADE NAME GRADE OR TYPE	MANUFACTURERS
Dehydrator Plugs (Spark Plugs)	Protek Plugs #9809	Chandler-Evans Corporation Meriden, Connecticut
Skin Protection (Magnaflux)	Magnaflux Hand Compound #2	The Magnaflux Corporation Chicago, Illinois
Corrosion Proofing Oil (Carburetors)	AMS-3070	Colonial Beacon Oil Co. 30 Rockefeller Plaza New York, New York
Corrosion Proofing Oil (engines)	AMS-3072	Dearborn Chemical Company Chicago, Illnois

MISCELLANEOUS

Electric Etcher	Martindale Standard #1	Martindale Electric Company Cleveland, Ohio
Metallizing Wire	Aluminum #11 containing 1 per cent zinc	Metallizing Engineering Co. 21-07 41st Avenue Long Island City, New York
Safety Wire	Stainless steel .040 Spec. 5685 #520A	The American Steel and Wire Co. 42-24 Orchard Street Long Island City, New York
Etching Fluid	Zincograph #1	The Langbein Company 285 Flatbush Avenue Brooklyn, New York
Etching Stamps	Wooden Pad Stamps	Krenzel Manufacturing Company Fulton Street, New York, N. Y.
Skin Protection (Magnaflux)	Economy Skin Shield	Standard Safety Equipment Co. Newark, New Jersey
Gasket Compound	Tite Seal	Radiator Specialty Company Charlotte, North Carolina
Gasket Compound	Gas Tite #2	United Oil Manufacturing Co. Erie, Pennsylvania

FORMULAS



Honing Coolant:

15 gallons Almag
1 gallon International Compound #155

* *

Grinding Coolant:

4 gallons International Compound #137
75 gallons water

* *

Valve Facing Coolant:

½ lb. Economy Lubricant E-1
5 gallons water

* *

Exhaust Valve Seat Grinding Coolant:

7 parts Mineral Seal Oil
1 part Cut-Max. Baste #2

* *

Magnaflux Inspection Fluid:

98% Varsol
2% Iron Oxide (paste or powder)

Di-Chromate Solution:

7½ quarts nitric acid
13 lbs. sodium di-chromate
32 qts. water

* *

Caustic Soda Solution:

85 lbs. caustic soda
18 lbs. tri-sodium phosphate
18 lbs. sodium cyanide
150 gallons of water

* *

Cadmium Plating Solution:

118.5 lbs. sodium cyanide
28.1 lbs. cadmium oxide
12.2 lbs. sodium hydroxide
28.1 lbs. ammonium sulphate
150 gallons water

* *

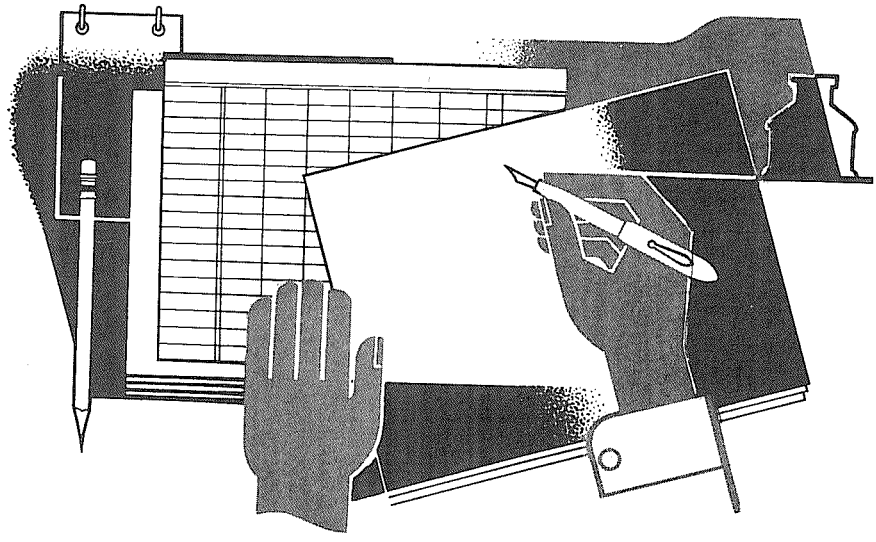
Muriatic Acid Mixture:

50% muriatic acid
50% water

* *

Ammonium Nitrate Mixture:

20% ammonium nitrate
80% water



SAMPLE FORMS

The following pages contain suggested sample forms for use in overhauling the engine. These forms are intended as samples which may have to be modified to suit individual overhaul shops.

The Engine Receiving Inspection Report should be filled out as the engine is received at the overhaul shop.

The Overhaul Inspection Record is used to record the condition of all parts, to record clearance and dimensions of parts and to list all parts which need to be replaced. It is also useful as a check-off list which reduces the possibility of overlooking any parts during inspection.

The Overhaul Test Log Sheet is used during the test run following overhaul. Its use has been fully described in Chapter VI.

Forms of the type listed in this section can be obtained upon application to the Service Department of Ranger Aircraft Engines.

ENGINE RECEIVING INSPECTION REPORT

Engine Model: Serial No: Date:

Part	Inspector's Remarks	Part	Inspector's Remarks
Shipping Box		Camshaft Housings	
Seals on Box		Reduction Gear Housings	
Engine Supports		Main Crankcase	
Propeller Shaft		Rear Crankcase	
Accessory Pads		Vertical Shaft Housings	
Baffles		Studs and Nuts	
Ignition Harness		Paint, General	
Intake Pipes		Rust, Location	
Intake Manifolds		Corrosion, Location	
Cylinder Fins		Engine Slushed	

ACCESSORIES

Accessory	Make	Model	Serial No.	Condition
Carburetor				
Starter				
Magneto				
Generator				
Fuel Pump				
Vacuum Pump				
Hydraulic Pump				
Gun Imp. Generator				
Spark Plugs				

REMARKS: (Missing Parts, Improper Packing, Openings left uncovered, etc.)

Inspector's Signature:.....

OVERHAUL INSPECTION RECORD

Engine Model: _____ Total Time: _____ Order No.: _____

Serial No.: _____ Time Since Overhaul: _____ Date: _____

CASTINGS	Studs & Dowels	Nicks & Cracks	Parting Surface
Main Crankcase			
Front Crankcase			
Rear Crankcase			
Breather Body			
Thrust Plate			
Accessory Covers			
Upper Vertical Support			
Lower Vertical Support			
Camshaft Housing			
Camshaft Housing Cover			
Camshaft Housing Front Plate			
Scavenger Pump Housing			
Scavenger Pump Cover			
Pressure Pump Housing			
Pressure Pump Cover			
Tachometer Drive Housing			
Engine Feet			
Hot Spot			
Front Manifold			
Rear Manifold			

GEARS	Teeth	Journals	Splines-Keyways
Crankshaft Gear			
Upper Idler			
Front Accessory Drive			
Rear Accessory Drive			
Right Rear Idler			
Left Rear Idler			
Right Magneto			
Left Magneto			
Tachometer Gear, Long			
Tachometer Gear, Short			

GEARS - continued	Teeth	Journals	Splines-Keyways
Tachometer Idler Gear			
Lower Idler Spur			
Lower Idler Bevel			
Upper Vertical Shaft			
Lower Vertical Shaft			
Camshaft Gear			
Scavenger Pump Driving			
Scavenger Pump Driven			
Pressure Pump Driving			
Pressure Pump Driven			

CYLINDERS	1	2	3	4	5	6
Condition of Cylinders						
Min. Barrel Diameter, Top						
Max. Barrel Diameter, Top						
Barrell Diameter, Bottom						
Spark Plug Inserts						
Intake Valve Guides						
Exhaust Valve Guides						
Intake Valve Seats						
Exhaust Valve Seats						
Intake Valves						
Exhaust Valves						
Rocker Arm Supports						
Pistons, Condition						
Piston Skirt Diameter						
Piston Pin Boss Diameter						
Piston Pin Diameter						
Piston Pin Condition						
Connecting Rod Bend						
Connecting Rod Bushing						
Connecting Rod Brg. Condition						
Connecting Rod Brg. Vert. Dia.						
Connecting Rod Brg. Horiz. Dia.						
Crankpin Diameter						

Foreman: _____ Inspector: _____

Serial No. _____ Date _____

CRANKSHAFT	1	2	3	4	5	6	7
Main Journal Diameter							
Main Bearing Vertical Diam.							
Main Bearing Horiz. Diam.							
Main Bearing Condition							

SHAFTS	Journals	Splines	Threads	Magnaflux Rejections
Crankshaft				
Accessory Drive				
Vertical Drive				
Camshaft				
Pressure Pump				
Scavenger Pump				

Crankshaft Spacer		Engine Mount Rubbers		Cam. Gear Shim Thickness	
Starter Dog		Intake Pipes		Valve Rocker Arms	
Large Crankshaft Plugs		Vertical Shaft Housing		Valve Adjusting Screws	
Crankshaft Dowels		Front Cylinder Baffle		Outer Valve Springs	
Crankshaft Damper Plate		Inter-Cylinder Baffles		Valve Locks	
Camshaft Damper Flywheel		Wire Manifold		Finger Strainer Magnets	
Cam. Damper Inner Retainer		Right Magneto No.		Oil Press. Relief Valve	
Thrust Bearing		Carburetor No.		Tachometer Adapter	
Thrust Plate Shim Thickness		Starter No.		Exhaust Adapters	
Low. Idler Gear Shim Thick.		Front Crankshaft Slinger		Fuel Pump Spacer	
Up. Vert. Shaft Shim Thick.		Rear Crankshaft Slinger		Intake Pipe Packing Nuts	
Camshaft Bushing		Small Crankshaft Plugs		Vert. Shaft Hsg. Packing Nuts	
Rocker Arm Roller		Crankshaft Balance Plug		Front Baffle Spring	
Inner Valve Springs		Crankshaft Damper Weights		Cylinder Head Baffles	
Valve Spring Washers		Camshaft Damper Weights		Recondition Spark Plugs	
Finger Strainers		Scav. Pump Drive Adapter		Left Magneto No.	
Main Oil Strainers		Thrust Bearing Nut		Fuel Pump No.	
Scav. Oil Pipe in Sump		Connecting Rod Bolts		Generator No.	
Generator Adapter		Up. Vert. Shaft Shim Thick.			

REWORKS AND MODERNIZATIONS

_____

_____

_____

_____

_____

Foreman: _____ Inspector: _____

NEW ENGINE PARTS REQUIRED

Serial No.: _____ Date: _____

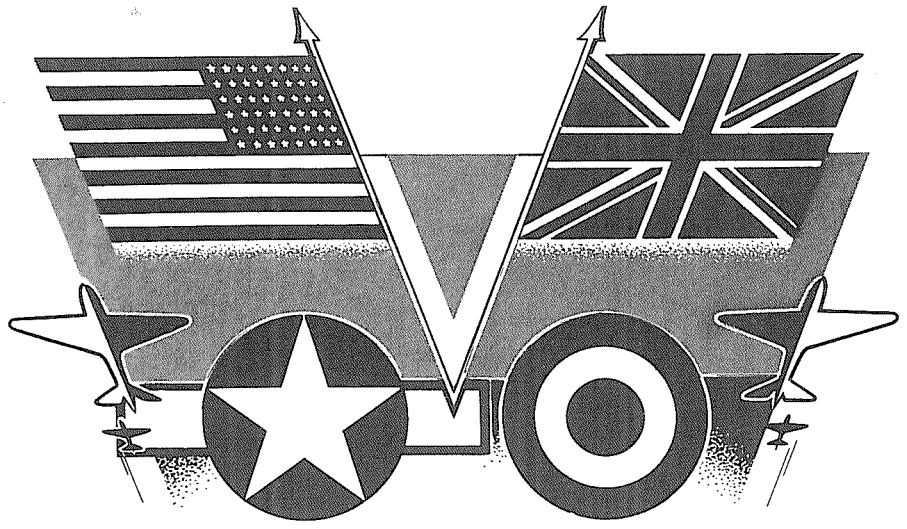
Quan.	Part No.	Description	Unit	Extension

Engine Model: # OVERHAUL TEST LOG SHEET **Engine Serial No.:**

ACCESSORIES	Carburetor	Magneto	Spark Plugs	Starter	Generator	Fuel Pump	Hydraulic Pump	Vacuum Pump
Manufacturer								
Model								
Serial Number			New or Used:					

TIME OF DAY		TOTAL TEST TIME		MAN PRESS	ENG. SPEED	Revolution Count				Fuel Cons.		FUEL PRESS	CARB AIR TEMP	OIL IN TEMP	OIL OUT TEMP	REAR OIL PRESS	NOSE OIL PRESS	OIL ON SCALES	OIL CONS	Cylinder Head Temps				Mark Location of Thermocouples ← Here
Hrs.	Min	Hrs.	Min.	"Hg	R.P.M.	FINISH REVS.	START REVS.	TOTAL REVS.	TIME SEC.	QUANT lbs.	CONS lbs./hr.	FUEL PRESS lbs./sq.in.	°F	°F	°F	lbs./sq.in.	lbs./sq.in.	lbs.	lbs./hr.	°F	°F	°F	°F	REMARKS
																								These numbers are given for reference
																								to text only and need not appear
																								on sheets actually used for recording
1		2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	32 ← Test Data

All Plugs Firing: 2550 RPM	Acceleration:	Fuel: Octane	Oil Flow Test: (Rated Power)	Test Club:		Tester:
Intake Plugs Only: RPM	Idling Speed: RPM	Oil: Sec. Saybolt Vis.	Time For lbs. Oil: Sec.	Barometer:	"Hg	Inspector:
Exhaust Plugs Only: RPM	Fuel Cut Off: Sec.	Idle Oil Press: lbs./sq.in.	Oil Flow: lbs./min.	Air Temperature:	°F	Date:



U. S.-BRITISH GLOSSARY

Standard American nomenclature has been used throughout this manual. Some of the expressions used have different meanings in the British Empire and in order to avoid confusion, the British equivalent for all terms which are peculiar to American technical language, have been listed below.

U. S. NAME	BRITISH EQUIVALENT	DESCRIPTION
Anti-Friction Bearing	Ball, Roller or Needle Bearing	A bearing which eliminates sliding friction by balls, rollers or needles which make only rolling contact with the races.
Battery	Accumulator	A device for storing electric energy.
Blade Connecting Rod	Plain Connecting Rod	Connecting rod with a plain big end which fits inside the big end of the forked rod.
Box Wrench	Ring Spanner	A wrench the end of which fits completely around the nut.
Bushing	Bush	A cylindrical insert which provides a bearing surface.
Cap Screw	Set-Screw	A threaded bolt which screws directly into a part without using a nut.

U. S. NAME	BRITISH EQUIVALENT	DESCRIPTION
Carburetor	Carburetter	A device for mixing fuel vapor with air in the correct ratio.
Check Valve	Non-return Valve	A valve which permits flow in only one direction.
Connecting Rod Bearing End	Big End	The end of a connecting rod which carries the connecting rod bearing.
Cotter Pin	Split Pin	Safetying device.
End Play	End Float	Axial play of shafts or gears.
Exhaust Stack	Exhaust Pipe (single)	A single exhaust pipe connected to the exhaust port of a cylinder.
Fillister Head Screw	Cheese Head Screw	Screw with cylindrical slotted head.
Fuel Valve	Fuel Cock	Means for shutting off fuel line.
Gall (to)	Fret (to)	Wear between similar metals caused by oscillating motion between parts.
Gasket	Joint or Washer	Material used to make a tight joint between parts.
Gasoline	Petrol	A petroleum product used as engine fuel.
Generator	Dynamo	A machine which changes mechanical energy into electrical energy.
Ground	Earth	Electrical symbol denoting connection to ground or to main body of aircraft or engine.
Intake Valve	Inlet Valve	The valve which admits fuel air mixture to the combustion chamber.
Kerosene	Paraffin Oil	A petroleum distillate.
Lean Mixture	Weak Mixture	Fuel-air mixture deficient in fuel vapor.
Lock Nut	Locking Nut	A nut to keep a screw from rotating.
Lock Ring	Circlip	A ring of spring steel wire used to lock parts in position.
Manifold Pressure	Boost	Pressure in intake system of engine.
Pad	Mounting Face	Machined surface used for mounting external parts or accessories.
Pilot	Spigot	A guide fitting a recess for location purposes.

U. S. NAME	BRITISH EQUIVALENT	DESCRIPTION
Piston Pin	Gudgeon Pin	The shaft which holds the piston to the connecting rod.
Piston Pin End	Small End	The end of a connecting rod which holds the piston pin.
Propeller	Airscrew	A device to convert rotary motion into thrust.
Propeller Hub	Propeller Boss	A device used to attach the propeller to the propeller shaft.
Rated Power	Normal Power	The highest continuous power output approved by the manufacturer.
Set Screw	Grub Screw	A machine screw threaded into one part and bearing on another which prevents relative motion.
Shaft	Spindle	A small shaft such as those used to carry the valve rocker arms.
Socket Wrench	Box Spanner	A tool for tightening nuts made of tubular stock.
Spanner Wrench	C Spanner	A tool for tightening slotted packing nuts.
Spark Plug	Sparking Plug	The unit which creates the spark in the combustion chamber of an engine cylinder.
Strainer (oil)	Filter (oil)	A device which filters the oil to remove impurities.
Tachometer	Engine Speed Indicator	An instrument which indicates rotary speeds of shafts in R.P.M.
Tag	Label	A piece of paper, cloth or sheet metal carrying identification marks and attached to object to be identified.
Test Club	Test Fan	A special propeller for testing engines.
Turning Bar	Tommy Bar	Bar used to turn a socket wrench. (Box Spanner).
Valve Lock	Collet	A split conical collar used to hold the valve spring washer on the valve stem.
Vise	Vice	A device for holding parts between two jaws which are tightened by a screw.
Wrench	Spanner	A tool used to tighten nuts.

CHAPTER IX

TABLE OF LIMITS

REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
1	Up. Fr. Idler Gear and Brg. in Crankcases—Dia.	.001L	.003L	.006L
2	Up. Fr. Idler Gear and Brg. in Crankcases Side Clearance	.003L	.015L	.020L
3	Accessory Dr. Shaft and Thrust Plug—Dia.	.0005L	.0025T	
4	Accessory Dr. Shaft Thrust Plug and Fr. Crankcase —End Clearance	.008L	.024L	.040L
5	Accessory Dr. Shaft and Fr. Drive Gear—Dia.	.0005L	.001T	
6	Accessory Dr. Shaft and Brgs. in Up. Crankcase— Diameter	.002L	.004L	.006L
7	Accessory Dr. Shaft and Rear Drive Gear—Dia.	.0005L	.0035L	
8	Accessory Dr. Shaft and Rear Dr. Gear—Spline Side Clearance	.000T	.004L	
9	Accessory Dr. Shaft Rear Gear and Brg. in Crank- cases—Dia.	.002L	.004L	.006L
10	Accessory Dr. Shaft Rear Gear and Crankcases— Side Clearance	.003L	.031L	.040L
11	Generator Adapter and Rear Crankcase—Pilot Dia.	.000T	.003L	
12	Rear Idler Gear and Brgs. in Crankcase—Dia.	.001L	.003L	.006L
13	Rear Idler Gear and Brgs. in Crankcase— Side Clearance	.004L	.028L	.040L
14	Magneto Dr. Gear and Brgs. in Crankcases—Dia.	.002L	.004L	.006L
15	Magneto Dr. Gear and Brgs. in Crankcases— Side Clearance	.004L	.028L	.040L
16	Magneto Dr. Gear and Magneto Dr. Coupling—Dia.	.000T	.002L	
17	Magneto Dr. Gear Oil Retainer and Crankcase—Dia.	.001T	.007T	
18	Magneto Dr. Gear and Pressure Oil Pump Dr. Shaft —Spline Side Clearance	.005L	.009L	
19	Pressure Oil Pump Dr. Shaft and Cover—Dia.	.001L	.003L	.006L
20	Pressure Oil Pump Dr. Shaft and Hsg.—Dia.	.001T	.003T	
21	Pressure Oil Pump Dr. Shaft and Drive Gear— Spline Side Clearance	.002L	.006L	
22	Pressure Oil Pump Driven Gear Shaft & Hsg.—Dia.	.001L	.003L	.006L
23	Pressure Oil Pump Driven Gear Shaft and Driven Gear—Dia.	.001L	.003L	.006L
24	Pressure Oil Pump Gears and Hsg.—Side Clearance	.001L	.007L	.010L
25	Pressure Oil Pump Gears and Hsg.— Diametral Clearance	.003L	.007L	.010L
26	Pressure Oil Pump Gears—Total Permissible Back- lash in Finished Pump		.010	.025

TABLE OF LIMITS—continued

REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
27	Pressure Oil Pump Cover and Rear Crankcase—Pilot Dia.	.001L	.003L	
28	Oil Pressure Relief Valve Spring Pressure at .500" Height (Wire Dia. .071")	9.5 lbs.—10.5 lbs.		
29	Vacuum Pump Driven Gear Oil Retainer & Hsg.—Diameter	.0005T	.0035T	
30	Tach. Dr. Idler Gear and Bushing—Dia. (Press Fit)	.0005T	.002T	
31	Tach. Dr. Idler Gear Bushing and Shaft—Dia.	.001L	.0025L	.006L
32	Tach. Dr. Idler Gear and Hsg.—Side Clearance	.001L	.009L	
33	Tach. Dr. Idler Gear Shaft & Rear Crankcase—Dia.	.0005L	.001T	
34	Tach. Dr. Idler Gear Shaft and Hsg.—Dia.	.0015L	.003L	
35	Tach. Gear and Insert—Dia.	.0015T	.0045T	
36	Tach. Gear and Adapter—Dia.	.001L	.003L	.006L
37	Tach. Gear and Hsg.—End Clearance	.002L	.020L	
38	Tach. Gear Adapter and Hsg.—Dia.	.0005L	.001T	
40	Thrust Bearing Nut—Tightening Torque	500-660 Foot-Pounds		
41	Thrust Brg. Nut and Fr. Cover—Dia.	.011L	.026L	
42	Thrust Brg. Fr. Cover and Fr. Crankcase—Pilot Dia.	.0009L	.0039L	
43	Thrust Brg. and Fr. Crankcase—Dia.	.0002L	.002L	.005L
44	Thrust Brg. and Fr. Crankcase—Clamp	.002T	.0093T	
45	Thrust Brg. and Crankshaft—Dia.	.0001L	.0012L	.0025L
46	Crankshaft and Crankshaft Gear—Dia.	.0006L	.0021L	
47	Crankshaft Gear and Key—			
	Side Clearance in Shaft	.0005L	.0015T	
	Side Clearance in Gear	.000T	.002L	
	Top Clearance in Gear	.0026L	.0141L	
48	Crankshaft and Oil Plugs—Dia.	.0015T	.0015L	.004L
49	Crankshaft and Hollow Dowel—Dia.	.001L	.005L	
50	Crankshaft and Starter Jaw—Dia.	.000T	.0015T	
51	Crankshaft and Starter Jaw and Key—			
	Side Clearance in Shaft	.000T	.002L	
	Side Clearance in Jaw	.0005L	.0015T	
	Top Clearance in Jaw	.0055L	.0165L	
53	Main Brg. and Crankshaft—When Assembled in Crankcase—Dia.			
	Vertical Axis	.0017L	.0042L	.007
	Horizontal Axis	.0027L	.0052L	
54	Main Brg. Studs and Crankcases—Dia.	.0017L	.0037L	
55	Main Brg. Hold-Down Nut-Tightening Torque	420-480 Inch-Pounds		
56	Connecting Rod Brg. and Crankpin—Dia.	.002L	.0045L	.007L

TABLE OF LIMITS—continued

REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
57	Connecting Rod Brg. and Crankpin—Side Clearance	.0064L	.0165L	
59	Connecting Rod Brg. and Connecting Rod—	.001T	.005L	
	Side Clearance	.000T	.004L	
60	Connecting Rod and Cap and Bolt—Dia.	.0000T	.0015L	
61	Connecting Rod Bolt-Tightening Stretch	.0035	.0045	
62	Connecting Rod and Bushing—Dia.	.002T	.004T	
63	Piston Pin and Bushing—Dia.	.001L	.0025L	.006L
64	Piston Pin and Piston—Dia.	.000T	.0015L	.003L
65	Piston Oil Scraper Ring—Gap			
66	Piston Oil Scraper Ring and Groove—	.020	.026	.040
	Side Clearance	.0005L	.002L	.0045L
67	Piston Compression Ring—Gap			
68	Piston Compression Ring and Bottom Groove—	.020	.026	.040
	Side Clearance			
69	Piston Compression Ring & Intermediate Groove—	.003L	.0045L	.006L
	Side Clearance			
70	Piston Compression Ring and Top Groove—	.005L	.0065L	.009L
	Side Clearance	.006L	.0075L	.011L
71*	Piston Skirt (Bottom) and Cylinder—Dia.	.013L	.017L	.027L
72*	Piston Skirt (Top) and Cylinder—Dia.	.017L	.021L	.031L
73	Piston Intermediate Land and Cylinder—Dia.	.026L	.030L	.040L
74	Piston Top Land and Cylinder—Dia.			
75	Cylinder Barrel Bore—	.029L	.033L	.043L
	Wear			.010
	Out-of-Round			.005
	Taper-per-inch		.001	
76	Cylinder Barrel and Crankcase—Pilot Dia.	.011L	.019L	
77	Cylinder Hold-Down Nut Tightening Torque	250-300 Inch-Pounds		
78	Spark Plug—Tightening Torque			
79	Valve Seat and Cyl. Hd. Intake and Exh.—	300-360 Inch-Pounds		
	Diameter (Shrink Fit)			
80	Valve Guide and Cyl. Hd. Intake—	.008T	.013T	
	Diameter (Shrink Fit)			
81	Valve Guide and Cyl. Hd. Exhaust—	.0015T	.003T	
	Diameter (Shrink Fit)	.002T	.0035T	
82	Intake Valve and Guide—Dia.	.002L	.004L	.009L
83	Exhaust Valve and Guide—Dia.	.003L	.005L	.010L
84	Valve Spring Pressure—			
	Outer (Wire Dia. .168″)			
	Compressed to 1-11/32″	59.8 Pounds		

TABLE OF LIMITS—continued

REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
	Compressed to 1-27/32"	35.1 Pounds		
	Inner (Wire Dia. .120")			
	Compressed to 1-5/16"	29.65 Pounds		
	Compressed to 1-13/16"	18 Pounds		
85	Valve Rocker and Bushing—Dia.	.002T	.004T	.007L
86	VaVlve Rocker Bushing and Shaft—Dia.	.0005L	.003L	
87	Valve Rocker Shaft and Support—Dia.	.000T	.0015L	.003L
88	Valve Spring Washer and Guide—Dia.	.0005L	.0035L	
89	Valve Rocker and Support—Side Clearance	.002L	.026L	
90	Valve Rocker and Shaft Support and Cam Housing Attach. Nut—Tightening Torque	120 Inch-Pounds		
91	Valve Rocker Roller and Spacer—Dia.	.0015L	.003L	.007L
92	Valve Rocker Roller and Rocker—Side Clearance	.0045L	.0105L	.015L
93	Valve Rocker Roller Spacer and Rivet—Dia.	.000T	.0025L	
94	Valve Rocker Roller Clearance—			
	When engine is cold—			
	For Timing (Intake	.015		
	(Exhaust	.015		
	For Running (Intake	.015		
	(Exhaust	.030		
95	Lower Fr. Idler Bevel Gear and Bearings— in Crankcases—Dia.	.002L	.004L	.006L
96	Lower Fr. Idler Bevel Gear and Spur Gear—Dia.	.0005L	.002T	
97	Lower Fr. Idler Bevel Gear and Key—			
	Side Clearance in Shaft	.000T	.0027T	
	Side Clearance in Gear	.0005T	.0025T	
	Top Clearance in Gear	.0045L	.016L	
98*	Thrust Washer for Bevel Gears	(See Note)		
99	Vert. Dr. Shaft Upper Bevel Gear & Support—Dia.	.001L	.003L	.006L
100	Vert. Dr. Shaft Upper Support and Fr. Crankcase— Pilot Dia.	.000T	.003L	
101	Vert. Dr. Shaft and Up. Bevel Gear—Dia.	.002L	.004L	
102	Vert. Dr. Shaft and Up. Bevel Gear— Spline Side Clearance	.007L	.011L	
103	Vert. Dr. Shaft and Lower Bevel Gear—Dia.	.002L	.004L	
104	Vert. Dr. Shaft and Lower Bevel Gear— Spline Side Clearance	.007L	.011L	
105	Vert. Dr. Shaft Lower Bevel Gear & Support—Dia.	.001L	.003L	.006L
106	Vert. Dr. Shaft Lower Support and Camshaft Hsg.— Pilot Dia.	.000T	.002L	

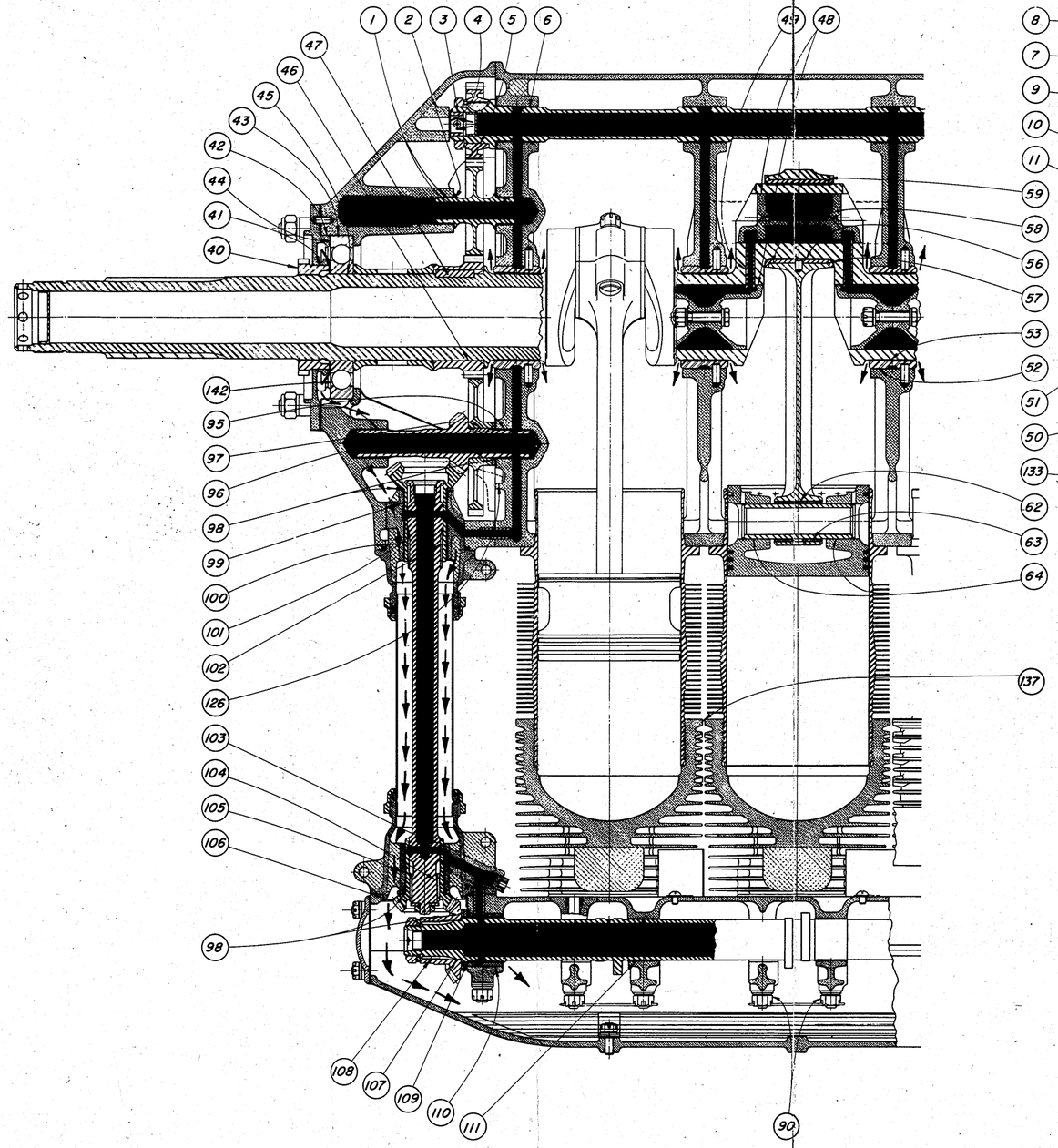
TABLE OF LIMITS—continued

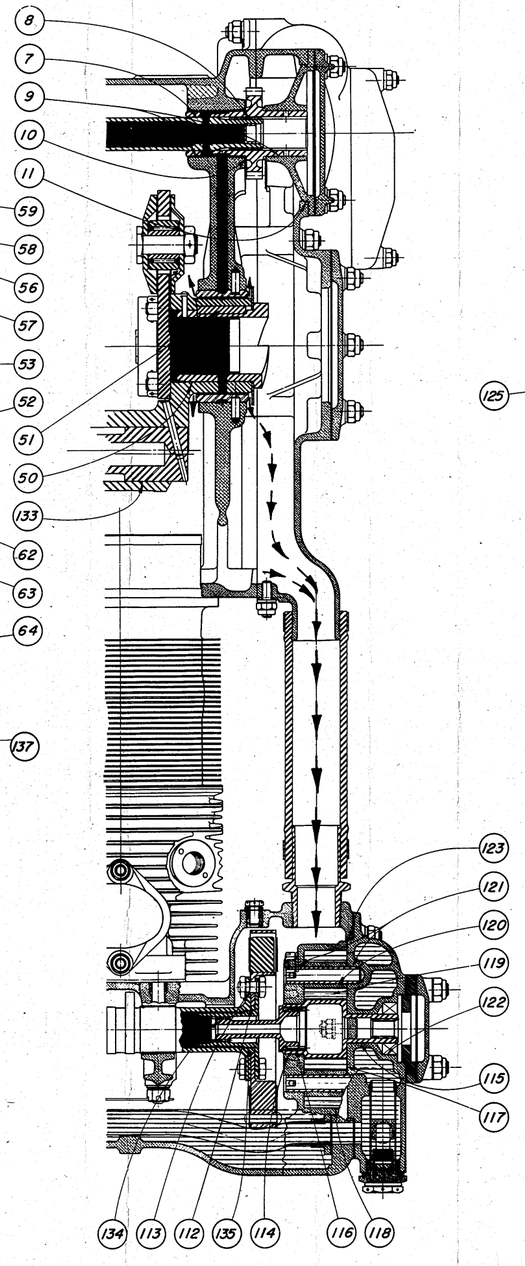
REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
107	Camshaft and Bevel Gear—Dia.	.000T	.002L	
108	Camshaft and Bevel Gear—Sline Side Clearance	.001L	.003L	
109	Camshaft and Bushing—Dia.	.002L	.004L	.006L
110	Camshaft Bushing and Hsg.—Dia.	.000L	.0015T	
111	Camshaft and Hsg.—Dia.	.003L	.005L	.009L
112	Camshaft and Flywheel—Dia.	.000T	.002L	.003L
113	Bolt and Camshaft Flywheel and Scavenge Oil Pump Dr. Adapter—Dia.	.000T	.0015L	.0025L
114	Scavenge Oil Pump Dr. Gear and Cover—Dia.	.001L	.003L	.006L
115	Scavenge Oil Pump Dr. Gear and Hsg.—Dia.	.001L	.003L	.006L
116	Scavenge Oil Pump Dr. Gear and Quill Shaft—Spline Side Clearance	.0045L	.0075L	
117	Scavenge Oil Pump Gears and Hsg.—Side Clearance	.001L	.007L	
118	Scavenge Oil Pump Gears and Hsg.—Diametral Clearance	.005L	.009L	
119	Scavenge Oil Pump Dr. Gear and Driven Gear—Total Permissible Backlash in Finished Pump		.010	.025
120	Scavenge Oil Pump Driven Gear and Shaft—Dia.	.001L	.003L	.006L
121	Scavenge Oil Pump Driven Gear Shaft & Hsg.—Dia.	.001L	.003L	
122	Scavenge Oil Pump Hsg. and Oil Retainer	.001T	.007T	
123	Scavenge Oil Pump Hsg. and Camshaft Hsg. and Cover—Pilot Dia.	.000T	.003L	
124	Mounting Bracket and Main Crankcase—Pilot Dia.	.001L	.005L	
125	Mounting Bracket and Bushing—Dia.	.0015T	.0015T	
126	Fr. Crankcase and Main Crankcase—Pilot Dia.	.001T	.003L	
127	Damper Weight to Plate—End Play	.010L	.015L	
128	Damper Bolt to Inner Race—Dia.	.0003L	.0012L	
129	Damper Weight Nut-Tightening Torque	450-500 Inch-Pounds		
120	Damper Attaching Nuts—Tightening Torque	200-250 Inch-Pounds		
131	Damper Attaching Bolt to Crankcheek—Dia.	.0005T	.001L	
132	Damper Bolt to Damper Weight	.0000T	.0015L	
133	Crankshaft and Rear Crankpin Oil Plug	.0015L	.0045L	
134	Scavenge Oil Pump Dr. Adapter and Quill Shaft—Spline Side Clearance	.004L	.008L	
135	Scavenge Oil Pump Dr. Adapter & Camshaft—Dia.	.000T	.003L	
136	Damper Ring and Plate—Dia.	.001L	.0045L	
137	Inter-Cyl. Clearance of Head—Fins	.010		
138	Oil Pressure Strainer Retaining Spring—(Wire Dia. .125) Pressure at 1-5/16" Height	9 Pounds		
139	Oil Pressure Relief Valve Seat and Hsg.—Dia.	.000T	.002L	

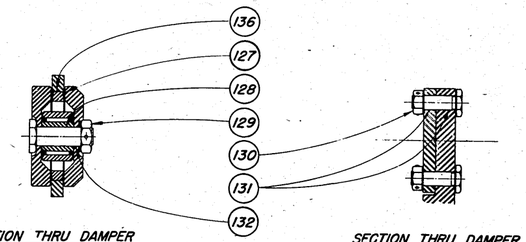
TABLE OF LIMITS—continued

REF. NO.	DESCRIPTION OF LIMIT	MINIMUM	MAXIMUM	REPLACE
140	Oil Pressure Relief Valve Spring— (Wire Dia. .055) Pressure at 1-5/8″ Height			
141	Pressure Oil Pump Dr. Shaft and Bushing—Dia.			
142	Prop. Shaft Thrust Brg.—End Play			
	Prop. Shaft Thrust Brg.—Tilt			
143	Retaining Nut and Camshaft Brg. Cap Fr.			
144	Retaining Nut to Camshaft Hsg. to Cyl. (619)			
	Retaining Nut to Camshaft Hsg. to Cyl. (181)			
145	Maximum allowable run-out at the front Prop. Cone Seat—.012			
146	Maximum allowable run-out of #4 Main Journal with respect to #1 and #7 Main Journals—.024			
147	Maximum allowable run-out of any Main Bearing Journal with respect to the two adjacent Main Bearing Journals—.005			

*NOTES	
71 72	Piston Skirt is cam ground .006 eliptical. Limits shown are on major axis of elipse at centerline of thrust face.
98	Grind thrust washers as required to align cone centers of mating bevel gears.
	Woodruff key and keyways conform with S.A.E. Specification.
	Backlash on all gears not otherwise shown .001—.007, replace at .025 backlash.
	All dowel pins have the following limits unless otherwise specified: Tight End .0005T Min.—.0025T—Max. Loose End .000T Min.— .002L—Max.
	All stake pins must be of a good drive fit.
	Drive all damper nut taper pins 1/32 below surface and stake over end.
	Replace circlet type piston pin retainer at each overhaul.
	Replace piston rings at each overhaul.
B	Connecting Rod bores, without bushings installed must be parallel within .005 in 3 inches. Piston Pin Bushing and Connecting Rod Brg. Bores to be parallel within .003 in 3 inches.

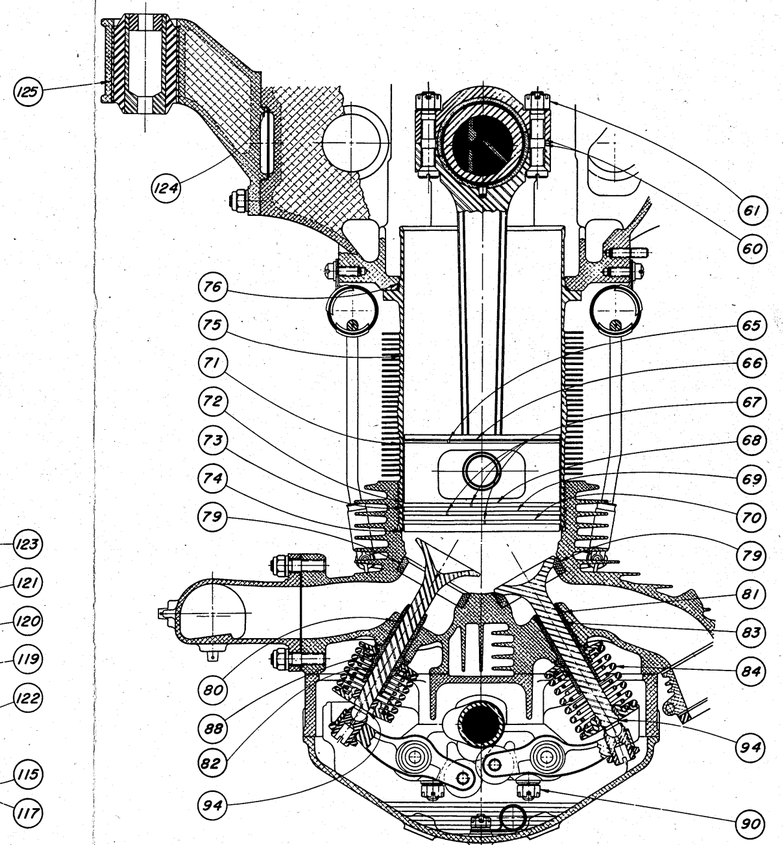






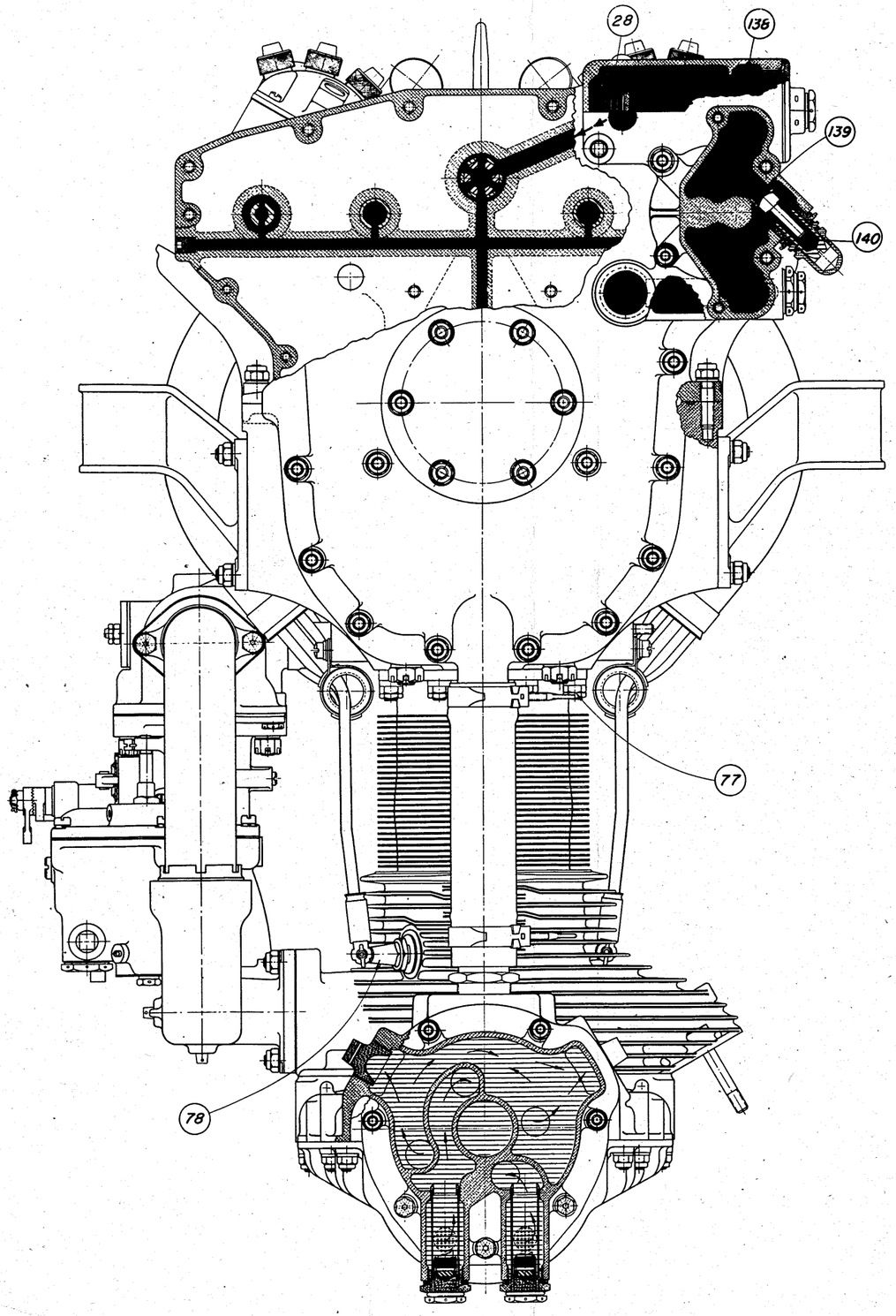
SECTION THRU DAMPER BEARING & WEIGHT.

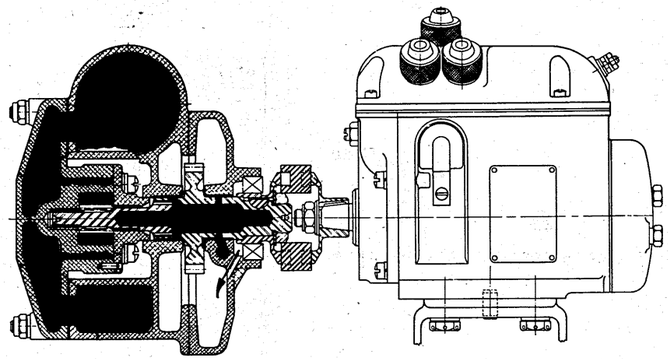
SECTION THRU DAMPER ADAPTER & CRANKSHAFT.



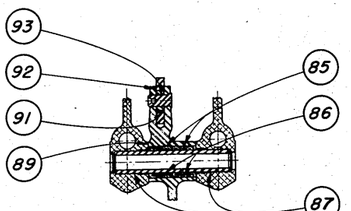
RANGER AIRCRAFT ENGINE
MODEL 6-440C
LIMITS AND LUBRICATION CHART

SHEET 1 OF 2 SHEETS





SECTION THRU PRESSURE OIL PUMP
& MAGNETO DRIVE.



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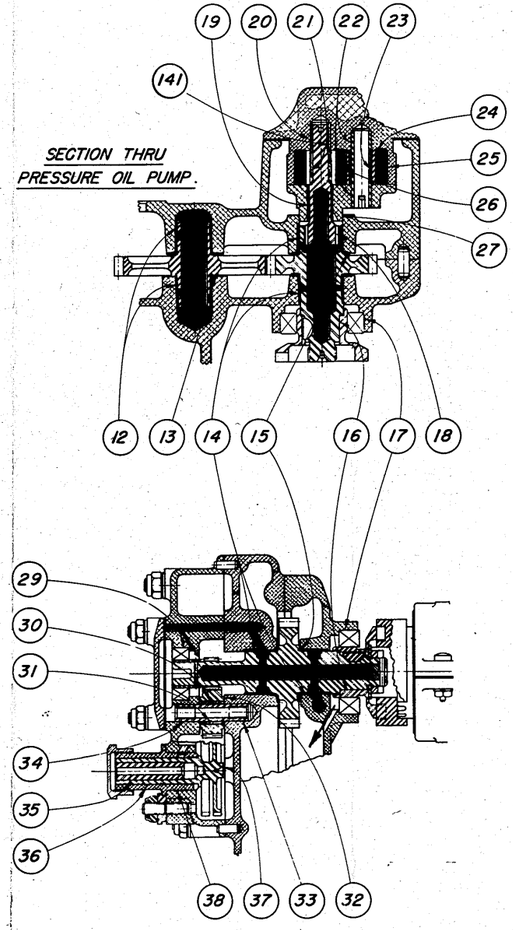
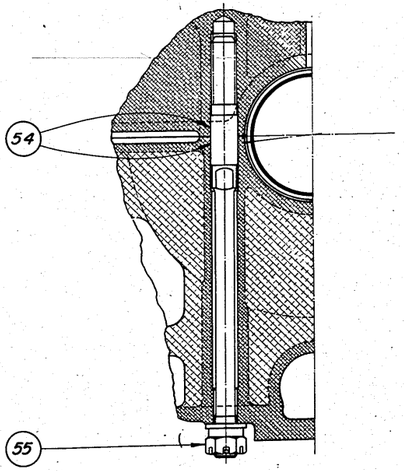
& SUPPORT.



SECTION THRU
PRESSURE OIL PUMP.

SECTION THRU VACUUM PUMP
& TACHOMETER DRIVE.



SECTION THRU CRANKCASE
& MAIN BEARING STUD.

RANGER AIRCRAFT ENGINE
MODEL 6-440 C
LIMITS AND LUBRICATION CHART

SHEET 2 OF 2 SHEETS